(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 April 2001 (19.04.2001)

PCT

(10) International Publication Number
WO 01/26573 A1

(51) International Patent Classification': A61S 18/20

(21) International Application Number: PCT/US00/26534

(22) International Filing Date:
27 September 2000 (27.09.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/415,575 8 October 1999 (08.10.1999) US

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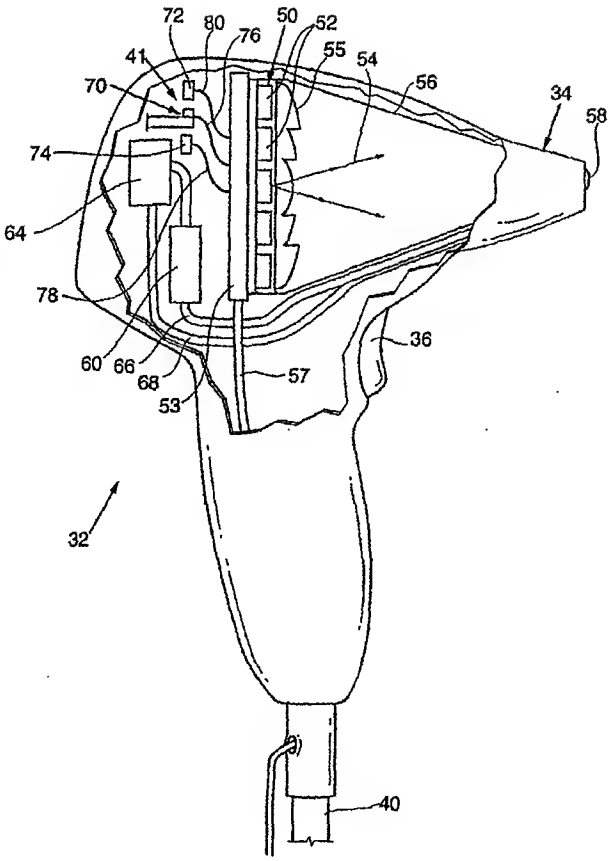
(81) Designated State *(national):IJP.*

(84) Designated States *(regional):* European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: AUTOMATIC FIRING APPARATUS AND METHODS FOR LASER SKIN TREATMENT OVER LARGE AREAS



(57) Abstract: Laser skin treatment apparatus includes a handpiece for delivering laser-radiation pulses from a laser to an area of skin being treated. The area being is larger than an area treatable in a single firing of the laser. The larger area is treated by treating adjoining sub-areas within the larger area by repeated firings of the laser. The laser is fired automatically depending on the position of the handpiece in the larger area. Several arrangements for determing the position of the handpiece are disclosed. These include optical detection by the handpiece of indicia drawn on the skin being treated; optical, magnetic, or mechanical detection of indicia on a separate guide for the handpiece or on a roller attached to the handpiece; and detection by determining time of travel of signals from a transponder in the handpiece to a fixed reference plane.

WO 01/26573 A1

AUTOMATIC! FIRING! APPARATUS! AND! METHODS! FOR LASER! SKIN! TREATMENT! OVER! LARGE! AREAS

TECHNICAL! FIELD! OF! THE! INVENTION

The! present! invention! relates! in! general! to apparatus! for! laser! skin! treatment,! such! as depilation. The! invention! relates! in! particular! to an! automatic! repeat! firing! system! for! laser! skin treatment! apparatus! which,! in! a! single! firing,! can treat! only! a! relatively! small! sub-area! of! an! area! of skin! to! be! treated.

DISCUSSION! OF BACKGROUND! ART

In! laser! dermatological! treatment! operations such! as! depilation,! an! area! of! skin! to! be! treated! may often! be! much! greater! than! the! area! which! can! be treated! by! a! single! firing! of! laser! apparatus. Typical! apparatus! for! laser! treatment! includes! a handpiece! for! delivering! laser! radiation! from! a! laser to! skin! being! treated.! The! laser! may! be! remote! from the! handpiece! with! the! laser! radiation! being delivered! to! the! handpiece! via! an! optical! fiber! or articulated! arm. Alternatively,! the! laser! radiation may! be! provided! by! a! diode-laser! array! incorporated in! the! handpiece. A! handpiece! is! often! furnished with! a! cooled! window! which! is! placed! in! contact! with the! skin,! laser! radiation! being! delivered! to! the! skin through! the! cooled! window.

Treatment! of! a! large! area! of! skin! is! typically accomplished! by! an! operator! manually! firing! the! laser apparatus,! with! the! handpiece! located! in! one! position on! the! area! of! skin! being! treated,! then! moving! the

handpiece! to! another! position! in! the! treatment! area and! manually! firing! the! laser! apparatus! again.! One disadvantage! of! this! method! is! that! it! can! be difficult! to! precisely! and! contiguously! locate treated! sub-areas! of! the! total! area! being! treated such! that! no! sub-area! is! left! untreated! and! no overlapping! of! treated! sub-areas! occurs. Another disadvantage! of! this! method! is! that! time! taken! to relocate! the! handpiece! from! a! treated! sub-area! to! an adjacent! untreated! sub-area! can! prolong! the! treatment operation. This,! in! turn,! can! lead! to! an! increased cost! of! the! operation.! The! apparatus! and! method! of the! present! invention! is! intended! to! overcome! these disadvantages.

SUMMARY! OF! THE! INVENTION

The! present! invention! is! directed! to! a! method! of treating! an! area! of! skin! with! a! laser! by! delivering! a series! of! laser-radiation! pulses! to! the! skin.! Each of! the! laser! pulses! treats! a! sub-area! of! the! area! to be! treated.

In! one! aspect! of! the! present! invention,! a! laser is! provided! which,! on! being! fired,! generates! a! pulse of! laser-radiation. A! handpiece! is! provided! and arranged! for! delivering! a! pulse! of! laser-radiation from! the! laser! to! the! skin! being! treated.

While! the! handpiece! is! being! moved! over! the! skin being! treated,! the! location! of! the! handpiece! in! the area! of! skin! being! treated! is! electronically determined,! and! the! laser! is! automatically! fired! when the! electronically! determined! location! corresponds! to a! sub-area! to! be! treated.

The! terminology! "automatically! fired"! here! means that! as! the! firing! of! the! laser! is! electronically triggered! by! the! electronic! position! determination without! operator! intervention! other! than! moving! of

the handpiece. The terminology "laser" means a laser resonator including a gain medium (which may be a diode-laser or array of same) and those electrical and electronic circuits needed to power the laser and to switch or modulate the laser to provide the laser-radiation pulses.

In one embodiment of the present invention the location determining step includes providing a plurality of regularly spaced indicia on or adjacent the area of skin being treated. At least one sensor is provide on the handpiece and arranged to detect passage of the handpiece by one or more of the indicia as the handpiece is moved over the skin being treated. The automatic firing is triggered by the passage of the handpiece by one or more of the indicia. The indicia may be graphic indicia, magnetic indicia, or mechanical indicia.

In one example of this preferred embodiment of the present invention, the indicia are graphic (optically detectable) indicia. The sensor includes a light-source arranged to direct light onto the skin being treated such that the thus directed light is scattered by the skin being treated. The sensor includes one or more light detectors arranged to detect the light scattered by the skin. The graphic indicia are equally-spaced parallel lines drawn on the area of skin being treated in a medium which is opaque to the wavelength of light emitted by the light-source and transparent to the wavelength of said pulse of laser radiation. Passage of the handpiece by any one of the indicia (crossing any one of the lines) results in a reduction in the scattered light detected by the detector. The reduction in scattered light indicating that one of said indicia has been passed, i.e., a line has been crossed.

In another embodiment of the present invention the location determining step comprises providing a roller on the handpiece, the roller being arranged to contact the skin being treated and rotate in response to the handpiece being moved over the skin being treated. The roller has a plurality of regularly spaced indicia thereon. At least one sensor is provided on the handpiece. The sensor is arranged to detect passage by the sensor of one or more of the indicia as the roller rotates. The automatic firing is triggered by the passage by the sensor of one or more of the indicia.

The indicia on the roller may be radially extending lines on a side of the roller or longitudinally extending lines on a cylindrical surface of the roller. The indicia in either case may be graphic (optically detectable) indicia or magnetic (magnetically detectable) indicia. In one variation of this embodiment, indicia can be omitted from the roller and the roller axially connected to a shaft encoder, the shaft encoder providing signals used for the electronic position determination.

In yet another embodiment of the present invention, the location determining step comprises providing a screen adjacent the skin being treated. A transponder is provided on the handpiece. The transponder is arranged to emit a regular train of signal-pulses toward the screen such that the signal-pulses are incident thereon and a return-pulse corresponding to each of the incident signal-pulses returns to the handpiece. A receiver is provided on the handpiece for receiving the return pulses. An elapsed time between emitting a signal-pulse and receiving a corresponding return-pulse is determined. The elapsed time is representative of the location of the handpiece.

The! signal-pulses! are! preferably! ultrasonic pulses. However,! the! use! of! other! forms! of! signal pulses! is! possible,! for! example! optical! pulses! or radar! pulses.

In! still! another! embodiment! of! the! present invention! the! location! determining! step! also! includes providing! a! transponder! on! the! handpiece.! The transponder! is! arranged! to! emit! a! regular! train! of signal-pulses! each! thereof! in! diverging! beam. At least! two! spaced-apart! receivers! are! provided. The receivers! are! located! in! a! position! remote! from! the handpiece,! within! the! divergence! of! the! beam,! for receiving! said! signal! pulses. Based! on! the! spacing of! the! receivers! and! an! arrival! time! of! the! signal pulses! at! the! receivers,! the! location! of! the handpiece! is! determined! in! at! least! length! and! width dimensions! of! the! area! of! skin! to! be! treated.! For! an area! of! skin! to! be! treated! which! is! contoured,! three spaced-apart! receivers! may! be! provided,! and! the location! of! said! handpiece! in! the! area! of! skin! to! be treated! determined! in! length! width! and! height dimensions.

In! another! aspect! of! the! present! invention,! the handpiece! may! be! equipped! with! a! skin! contact-sensor for! determining! whether! or! not! the! handpiece! is! in contact! with! skin! being! treated.! This! is! useful! in laser! skin! treatments! wherein! laser! radiation! is delivered! to! the! skin! via! a! lens! or! transparent! body (applicator)! incorporated! in! the! handpiece! and! in contact! with! the! skin! for! promoting! efficient coupling! of! laser! radiation! into! dermal! layers.

In! one! preferred! embodiment! of! skin-contact sensing! in! accordance! with! the! present! invention,! a light-source! is! provided! having! an! exit-aperture thereof! on! the! handpiece.! The! exit-aperture! is configured! to! be! in! contact! with! the! skin! being

treated! when! the! applicator! is! in! contact! with! the skin! being! treated.! Light! from! said! light-source! is delivered! via! said! exit-aperture! thereof! such! that, when! the! applicator! is! in! contact! with! the! skin, light! delivered! the! said! exit-aperture! is! transported laterally! through! the! skin! via! volume! scattering! of the! light. A! detector! is! provided! having! a receiving-aperture! on! the! handpiece! proximate! the light-source! exit-aperture. The! output! of! the detector! is! monitored.! The! monitored! detector-output is! interpreted! as! an! indication! that! the! applicator of! the! handpiece! has! made! or! lost! contact! with! the skin! being! treated.

The! above-described! contact! skin! contacting method is not! limited! to! a! handpiece! delivering laser-radiation! for! skin! treatment! but! is! applicable to! handpiece! delivering! electromagnetic! radiation (for! skin! treatment)! from! an! incoherent! source! such as! a! flashlamp.! An! above-described! sensor! for detecting! graphic! indicia! may! be! configured! to additionally! function! as! a! skin! sensor! for implementing! the! above-described! skin-contact! sensing method.

Preferred! embodiments! of! the! present! invention are! described! in! detail! hereinbelow! with! reference! to a! laser! hair! removal! apparatus! using! an! array! of diode-lasers. Automatic! firing! arrangements! in accordance! with! the! present! invention! are! neither limited! to! apparatus! including! diode-lasers,! nor limited! to! hair! removal! apparatus.! Those! skilled! in the! art! will! recognize! that! automatic! firing principles! of! the! present! invention! are! applicable! to laser! apparatus! including! other! laser! types,! for example,! solid-state! lasers,! to! apparatus! wherein treatment! light! is! provided! by! an! incoherent! source of! electromagnetic! radiation! such! as! a! flashlamp,! and

to other laser skin treatments, for example, treatment of vascular lesions such as "port wine" stains.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, schematically illustrate a preferred embodiment of the present invention, and together with the general description given above and the detailed description of the preferred embodiment given below, serve to explain the principles of the invention.

FIG. 1 is a perspective view schematically illustrating a first preferred embodiment of laser treatment apparatus in accordance with the present invention having a first handpiece including a chilled tip and having a position sensor located therein, the handpiece being movably connected to a control console for controlling operating parameters of the apparatus.

FIG. 2 is a rear elevation view of the handpiece of FIG. 1 schematically illustrating the handpiece being moved in a direction orthogonal to a regular grid of parallel lines drawn on an area of skin being treated.

FIG. 3 is a partially-cutaway side elevation view of the handpiece of FIG. 1 schematically illustrating a light-source and photodetectors of the position sensor for respectively sending light to and receiving light from optical apertures in the tip of the handpiece.

FIG.!4 is! a! partial! front! elevation! view! of! the handpiece! of FIG.!1 schematically! illustrating details! of! the! chilled! tip! of! the! handpiece! and optical! apertures! of! the! sensor! therein.

FIG.!5 is! a! partial! cross-section! view! of! the handpiece! of FIG.!1 seen! generally! in! the direction 5-5 of! FIG.! 4! and! schematically illustrating! further! details! of! the! position! sensor in! the! handpiece.

FIG.!6 is! a! rear! elevation! view! schematically illustrating! a! second! handpiece! in! accordance! with the! present! invention! arranged! for! automatic! firing in! both! longitudinal! and! lateral! directions! of! motion thereof.

FIG.! 7! is! a! partial! front! elevation! view! of! the handpiece! of FIG.!6 schematically! illustrating details! of! the! chilled! tip! of! the! handpiece! and optical! apertures! of! four! position! sensors! therein.

FIG.!8 is! a! partial! rear! elevation! view schematically! illustrating! a! third! handpiece! in accordance! with! the! present! invention! arranged! for automatic! firing! by! sensing! crossings! of! lines! on! a ruled! guide-strip! placed,! rulings! uppermost,! in contact! with! skin! being! treated.

FIG.! 9! is! a! front! elevation! view! of! the handpiece! of! FIG.! 8! schematically! illustrating details! of! position! sensors! for! detecting! the! line-crossings.

FIG.!10 is! a! partial! side! elevation! view! of! the handpiece! of FIG.!8, schematically! illustrating

further! details! of! one! of! the! position! sensors! for detecting! the! line-crossings.

FIG.! 11! is! a! partial! plan! view! of! the! handpiece of FIG.!8 seen! in! the! direction! it-il! of FIG.!9 and schematically! illustrating! further! details! of! the position! sensors! for! detecting! the! line-crossings! and further! details! of! the! ruled! guide-strip! of FIG.!8.

FIG. 12 is! a! partial! side! elevation! view schematically! illustrating! a! fourth! handpiece! in accordance! with! the! present! invention! arranged! for automatic! firing! by! sensing! crossings! of! lines! on! a ruled! guide-strip! placed! on! edge,! rulings! facing sideways,.! in! contact! with! skin! being! treated.

FIG.! 13 is! a! front! elevation! view! schematically illustrating! further! details! of! the! handpiece! of FIG. 12 including! a! side-looking! position! sensor! for sensing! the! line-crossings.

FIGS.! 14 and! 15! are! partial! side! elevation! views schematically! illustrating! opposite! sides! of! a! fifth handpiece! in! accordance! with! the! present! invention arranged! for! automatic! firing! by! sensing! crossings! of radial! lines! on! wheel! attached! thereto,! the! wheel arranged! to! contact! skin! being! treated.

FIGS.! 15A and 15B are,! respectively,! side! and front! elevation! views! schematically! illustrating details! of! a! skin-contact! sensor! head! for! the handpiece! of FIGS. 14 and! 15.

FIG. 15C! is! a! front! elevation! view! schematically illustrating! details! of! an! alternative! skin-contact sensor! head! for! the! handpiece! of FIGS. 14 and 15.

FIG. 15D is a graph schematically illustrating detector output as a function of distance from various surfaces of a skin-contact sensor head in accordance with the arrangement of FIG. 15C.

FIG. 16 is a plan view from above schematically illustrating further details of the handpiece of FIGS. 14 and 15.

FIG. 17 is a partial side elevation view schematically illustrating opposite sides of a sixth handpiece in accordance with the present invention having a wheel attached thereto and connected to a shaft encoder, the wheel arranged to contact skin being treated and the handpiece arranged for automatic firing responsive to signals provided by the shaft encoder.

FIG. 18 is a plan view of the handpiece of FIG. 17 seen generally in the direction 18-18 of FIG. 17 and schematically illustrating further details of the wheel and a shaft-encoder and bearing housing on the tip of the handpiece.

FIG. 19 a side elevation view schematically illustrating a ninth handpiece in accordance with the present invention, having a detachable housing including a roller cooperative with a position sensor.

FIG. 20 is a perspective view schematically illustrating the detachable housing and roller of FIG. 19.

FIG. 20A is a perspective view schematically illustrating an alternative form of roller for the handpiece of FIG. 19.

FIG. 21 is a plan view from below schematically illustrating the handpiece of FIG. 19 without the detachable housing and showing a vertically-oriented position sensor head for sensing rotation of the roller of FIG. 20.

FIG. 22 is a perspective view schematically illustrating a seventh handpiece in accordance with present invention, including a transponder, for sending a signal to a screen located proximate a patient being treated, and a receiver for receiving an echo of the signal from the screen for determining the position of the handpiece in one dimension relative to the patient.

FIG. 23 is a perspective view schematically illustrating an eighth handpiece in accordance with present invention, including a transponder for sending a signal to three direction sensitive detectors proximate a patient being treated, signals from the detectors being used for determining the position of the handpiece in at least two dimensions relative to the patient.

DETAILED DESCRIPTION OF THE INVENTION

Turning now to the drawings, wherein like features are designated by like reference numerals, FIG. 1 depicts a first preferred embodiment of laser skin treatment apparatus 30 in accordance with the present invention. Apparatus 30 includes a handpiece 32 including a diode-laser array (not shown in FIG. 1) for providing laser radiation for treatment. The diode-laser array is alternatively referred to

hereinafter simply as the laser. The diode-laser array emits at a wavelength between about 790 and 830 nanometers (nm). This wavelength range should not be construed, however, as limiting the present invention.

In a tip 34 of handpiece 32 are located optical apertures of a position sensor incorporated in the handpiece. The apertures and other components of the position sensor are not shown in FIG. 1 but are described in detail further hereinbelow. The handpiece is activated by a trigger 36.

Apparatus 30 includes a control console 38. Control console 38 includes, inter alia, power-supplies, a water-supply and control electronics for components of handpiece 32. The control electronics and power and water supplies are connected to handpiece 32 via an umbilical sheath 40. When not in use, handpiece 32 may be "parked" in a receptacle 42 in control console 38. The operating sequence and treatment parameters for the apparatus are controlled from a touch-screen display 43.

Referring now to FIG. 2, in one preferred method of operating apparatus 30, a grid 44 of equally-spaced parallel lines **46 is** drawn on skin 48 being treated. The grid preferably covers the entire area of skin on which treatment is desired. Lines 46 are preferably spaced apart by a distance equal to a linear dimension of the area treatable in a single firing of the laser or a sub-multiple of that dimension. Preferably, the area treatable in a single laser firing is made square, or at least rectangular, in which case the spacing of lines 46 is made equal to the width or length of the area or some sub-multiple thereof. Handpiece 32 is moved in a direction orthogonal to lines 46 as indicated by

arrows! A,! with! tip! 34! of! the! handpiece! in! contact with! skin! 48.

When! the! handpiece! is! initially! applied! to! the skin,! the! output! of! detectors! 72! and! 74! (FIG.! 3)! is stored! by! the! control! electronics! of! console! 38! to form! a! baseline! reading. This! baseline! reading! will vary! depending! on! the! skin! reflectivity! at! the illuminating! wavelength! and! will! be! lower! for! darker skin! types. The! detection! of! lines! on! the! skin! is based! on! a! drop! in! detector! output! below! a predetermined! fixed! percentage! of! this! baseline reading. As! handpiece! 32! is! moved! over! skin! 48! the position! sensor! of! the! detectors! and! control electronics! detect! the! crossing! of! a! line! 46! and firing! of! the! laser! is! triggered.

When! apparatus! 30! is! in! the! automatic! firing mode,! depressing! trigger! 36! on! handpiece! 32! acts! to enable! automatic! firing! of! the! laser.! The! laser! will not! fire,! regardless! of! detected! line! crossings, unless! trigger! 36! is! also! depressed.

After! reaching! an! extreme! one! of! lines! 46, handpiece! 32! is! moved! laterally! by! the! width! of! the area! treatable! in! the! single! laser! firing,! and handpiece! 32! is! again! moved! in! the! direction indicated! by! arrows! A.! The! foregoing! sequence! is repeated! until! the! desired! area! is! treated. Movements! of! handpiece! 32! in! the! direction! indicated by! arrows! A! may! be! all! made **in** the! same! direction,! or alternating! between! forward! and! reverse! directions.

Referring! next! to! FIG.! 3,! FIG.! 4! and! FIG.! 5, further! details! of! handpiece! 32! and,! in! particular, of! the! position! sensor! therein! (designated! by numeral! 41! in! FIG.! 3),! are! described.! As! noted above,! handpiece! 32! includes! a! diode-laser! array.! In a! preferred! example,! a! diode-laser! array! 50! includes a! total! of! ten! diode-laser-bar! stacks! 52! arranged

into! rows! of! five.! Each! diode-laser-bar! stack! has! a total! of! nineteen! individual! edge-emitting! diode-lasers. The! diode-lasers! emit! light! at! a! wavelength between! about! 790! and! 830! nanometers! (nm).! Diode-laser! array! 50! is! assembled! on! a! water-cooled backing-plate! 53. Water! is! supplied! to! backing-plate! 53! from! control! console! 38,! via! a! conduit! 57 extending! through! umbilical! sheath! 40. Arranged! in this! way,! diode-laser! array! 50! can! deliver! up! to! 1600 Watts! (W)! of! laser-radiation.

Laser-radiation! 54! from! diode-laser! array! 50! is converged! in! the! fast! axis-of! the! diode-laser! bars! by cylindrical! microlenses! (not! shown)! associated! with stacks! diode-laser-bar! stacks! 52,! and! converged! in the! slow! axis! of! the! diode-laser! bars! by! a! Fresnel lens! 55. The! laser! radiation! is! then! guided! by! a tapered! light-guide! 56! toward! a! lens! 58,! preferably of! sapphire,! in! tip! 34! of! handpiece! 32.! Lens! 58! most preferably! has! a! square! aperture! to! facilitate "tiling"! together! of! sub-areas! treated! by! single firings! of! the! laser! as! described! above! with reference! to! FIG.! 2.

Lens! 58! has! a! contact! surface! 59! and! is! cooled by! a! cooling-fluid,! preferably! a! mixture! of! water! and ethylene! glycol,! chilled! by! a! thermo-electric! cooler (TEC)! 60! (see! FIG.! 3).! The! cooling-fluid! is circulated! through! a! copper! microchannel-cooling jacket! 62! (see! FIG.! 5)! in! thermal! contact! with lens! 58. Circulation! of! the! cooling-fluid! is effected! by! a! pump! 64! via! delivery! and! return conduits! 66! and! 68! respectively! (see! FIG.! 3).

Sensor! 41! includes! a! light-source! 70! (see FIG.! 3),! preferably! a! semiconductor! light-source, such! as! a! light-emitting! diode! (LED)! or! the! like,! and two! photodetectors! 72! and! 74,! such! as! photodiodes. These! photodetectors! are! connected! via! electrical

connections! (not! shown)! through! umbilical! sheath! 40 to! control! electronics! in! console! 38.

Light! from! light-source! 70! is! guided! by! an optical! fiber! 76! to! tip! 34! of! handpiece! 32! (see FIGS.! 3,! 4! and! 5).! Light! exiting! optical! fiber! 76 incident! on! skin! 48! is! scattered! through! upper! layers of! the! skin.! A! portion! of! the! scattered! light! enters optical! fibers! 78! and! 80! on! opposite! sides! of! optical fiber! 76. The! end! faces! of! optical! fibers! 76,! 78, and! 80! can! be! considered! as! apertures! of! the! position sensor! 41! of! handpiece! 32.! Preferably! these! end faces! are! equally! spaced! in! a! straight! line! as! shown in! FIG.! 4.! Optical! fibers! 76,! 78,! and! 80! can! be considered! as! having! proximal! ends! thereof! adjacent light-source! 70! and! detectors! 72! and! 74! respectively, and! distal! ends! thereof! in! tip! 34.

It! is! also! most! preferable! that! the! optical-fibers! are! arranged! at! an! angle! to! each! other! in tip! 34! of! handpiece! 32.! The! angle! converges! towards the! distal! ends! of! the! fibers.! The! angle! is! selected to! minimize! the! possibility! of! light! from! optical fiber! 76! entering! optical! fibers! 78! or! 80! by! specular reflection! from! any! surface.! One! arrangement! found to! be! optically! effective! and! mechanically! convenient is! that! the! fibers! 78,! 76! and! 80! have! a! diameter between! about! 0.5! and! 1.5! millimeters! (mm)! and! are set! the! angles,! in! order! 0! degrees,! 15! degrees,! and 30! degrees! from! the! vertical! (perpendicular! to skin! 48). The! distal! ends! of! the! fibers! are preferably! as! close! to! each! other! as! is! consistent with! securely! retaining! them! in! the! sensor! head.! One reason! for! this! is! discussed! further! hereinbelow.

It! is! important! that! lines! 46! are! drawn! with! a medium! (ink,! paint! or! the! like)! which! is! transparent to! laser-radiation! 54! from! diode-laser! array! 50,! but absorbent! for! light! from! light-source! 70. Light! from

light-source 70 must also be able to penetrate skin 48. By way of example, it has been found that for laser-radiation having a wavelength between about 790 and 830 nm, and a light-source 70 in a form of an LED emitting at a wavelength of about 660 nm, an ink containing the dye "Basic Blue 1" (CAS number 3251-06-0) is effective as a medium for lines 46.

Continuing now with particular reference to FIGS. 2 and 5, when end faces of optical fibers 76, 78 and 80 in tip 34 of handpiece 32 are all in contact with skin 48 in a region thereof between lines 46 (or outside grid 44 altogether) both optical fibers 78 and 80 will receive scattered light from optical fiber 76. The light so received will be transmitted to detectors 72 and 74. Control electronics connected to the detectors will record what may be described as a bright condition of the detectors.

As handpiece 32 is moved in the direction indicated by arrows A, either optical fiber 78 or optical fiber 80 will pass over a line 46 depending on the direction of movement (forward or reverse) of handpiece 32. If the width of lines 46 is equal to or greater than the diameter of the optical fibers, the optical fiber instantly over the line 46, and the detector associated therewith, will receive less scattered light because of the absorption of the line-marking medium. In this case, the control electronics will record a dark condition for that detector. Providing two detectors and associated optical fibers, arranged as shown and discussed provides the control electronics with a means of determining the direction of travel of handpiece as discussed below.

The control electronics are preferably programmed to record a "line-crossing" only after

both! detectors 74 and 76 have! registered! a! dark condition,! in! sequence. The! sequence! in! which! the dark! conditions! occur! determines! the! direction! of travel. The! recorded! line-crossing! is! used! by! the control! electronics! to! trigger! a! firing! of! the! laser for! treatment. The! number! of! line-crossings! recorded can! be! used! to! establish! a! position! of! tip 34 of handpiece! with! respect! to! a! starting! (datum)! point! or line.

Another! advantage! of! providing! the! above-discussed! two! detectors! and! fibers! is! in! providing! a means! for! determining! whether! or! not! tip 34! of handpiece 32! is in! contact! with! skin 48. If! tip! 43 loses! contact! with! skin! 48,! detectors 72 and 74! will simultaneously! register! a! dark! condition. Control electronics! can! be! programmed! to! use! such! a! recorded simultaneous! dark! condition! to! prevent! firing! of! the laser! either! automatically! or! manually,! thereby preventing,! for! example,! firing! the! laser! in! an attitude! where! it! may! be! therapeutically! ineffective.

The! time! interval! between! line-crossings! can! be used! to! determine! the! speed! of! travel! of! tip 34 of handpiece! 32! over! skin 48. One! reason! for! requiring knowledge! of! the! speed! of! travel! is! to! prevent handpiece! 32! from! being! moved! so! quickly! that,! at! the maximum! practical! firing! rate! of! diode-laser array! 52,! (the! laser)! sequentially! treated! sub-areas of! skin 48 can! not! be! contiguous.! By! way! of! example, in! above-described! apparatus! 30,! the! maximum! firing rate! is! between! about! four! and! eight! Hertz! (Hz). Another! reason! is! that! too! rapid! a! motion! can! reduce the! effectiveness! of! chilled! lens! 58! in! cooling! skin to! be! treated.

To! optimally! prevent! such! occurrences,! it! is desirable! to! know! the! speed! of! travel! of! the handpiece! before! it! has! moved! completely! out! of! a

last-treated sub-area of skin 48, and preferably also before the laser is first fired. This can be achieved by spacing lines 46 at some sub-multiple of the width (or length) of a treated sub-area, for example at one-half or one-third that width. Correspondingly, respectively two or three sequential line-crossings will need to be recorded by the control electronics of console 38 in order to trigger a laser firing, while consecutive recorded sequential line-crossings are used to determine the speed of travel of handpiece 32.

From the speed of travel determination, it is possible to provide a simple audible or visual warning of excess speed of travel and even to prevent firing of the laser if a predetermined speed threshold is exceeded. Referring again to FIG. 2, a simple visual display may take the form of three different colored LEDs 82, 84, and 86, located on the back of handpiece 32, these diodes being activated, for example, according to whether the rate of travel is respectively slower than optimal, optimal, or faster than optimal. Those skilled in the art may devise other speed display forms without departing from the spirit and scope of the present invention such as an (apparently) moving bar type or "thermometer" type display of the type often used for sound level indication in electronic sound recording apparatus.

Reasons for preventing a laser firing, be they related to speed of travel or lack of contact, and the position at which firing was prevented can be displayed on display 43 of console 38. This provides that an operator can correct the reasons for prevention of firing and resume automatic firing at the point of termination, or treat individual

untreated! sub-areas,! one! by! one,! by! manually! firing the! laser.

It! is! pointed! out! here! that! instead! of! lines drawn! in! a! medium! which! is! darker! than! the! skin! as discussed! above,! it! is! also! possible! to! employ! an medium! (ink)! containing! a! fluorescent! agent! such! as fluorescein! (resorcinolphthalein,! $C_{20}H_{12}O_5$)!. When excited! by! light,! for! instance! from! a! light-source (LED)! 70,! having! a! wavelength! centered! near! 494! nm, fluorescein! emits! light! centered! at! 520! nm.! A detector! with! a! matched! filter,! for! example! an interference! filter! having! a! passband! full! width! at half! maximum! transmission! (FWHM)! of! 10! nm,! at! a! peak transmission! wavelength! of! 520! nm,! can! selectively detect! this! fluorescent! emission. Here,! since! light emission! is! being! detected! rather! than! light absorption,! line! crossings! can! be! detected! equally effectively! on! skin! of! any! natural! color.

It! should! be! noted,! here,! that! in! this specification,! it! is! contemplated,! unless! otherwise stated,! that! any! computation! or! signal! evaluation required! for! position! determination,! laser! firing decisions! and! the! like! is! accomplished! by! one! or! more electronic! processors! in! control! circuitry! of console! 38. Communication! for! this! purpose! with devices! incorporated! in! handpiece! 32! and! any! below described! variations! thereof! is! accomplished! via umbilical! sheath! 40! as! exemplified! above. Any! remote displays! or! sensor! devices! are! assumed! to! be connected! directly! to! control! electronics! of console! 138. It! is! emphasized,! here,! that! this assumption! is! made! at! least! for! convenience! of description! and! should! not! be! considered! limiting. Those! skilled! in! the! art! will! recognize! that processing! devices! could! be! located! remote! from console! 38,! proximate! deviceb! which! electronic

control! is! required,! for! example,! in! a! handpiece! 32, or! in! a! computer! such! as! a! personal! computer! (PC). Should! such! remote! processing! devices! be! used,! the manner! of! interconnection! of! the! processing! devices will! be! evident! to! those! skilled! in! the! art! from! the functional! descriptions! of! embodiments! presented herein.

Continuing! now! with! a! description! of! other preferred! embodiments! of! the! present! invention,! a preferred! apparatus! and! method! of! the! present invention! is! described! above! in! terms! of! automatic firing! by! detecting! crossings! of! lines! in! a! parallel grid! of! lines! drawn! on! skin! to! be! treated! with! manual lateral! shifting! of! handpiece 32 between! linear automatic! firing! sequences.! In! another! preferred method! and! apparatus! in! accordance! with! the! present invention,! automatic! firing! is! provided! for! both longitudinal! and! lateral! movement! of! handpiece 32. A brief! description! of! this! method! and! apparatus! is! set forth! below! with! reference! to FIG.!6 and FIG. 7

Referring! first! to FIG.!6, a! grid 44X is! drawn on! skin 48 being! treated! using! a! medium! of! the! types discussed! above. Grid **44X** comprises! above-discussed equally-spaced! parallel! lines 46 and,! additionally, another! set! of! equally-spaced! parallel! lines 46X orthogonal! to! lines **46.** Lines 46 and **46X** are preferably! spaced! apart! by! a! distance! equal! to respectively! the! length! and! width! of! the! area treatable! in! a! single! firing! of! the! laser! or! a! sub-multiple! of! that! dimension.! If! the! area! treatable! in a! single! laser! firing! is! made! square,! of! course,! the spacing! of! lines 46 and 46X is! equal. Longitudinal and! lateral! motion! is! designated! in FIG. 6 by! arrows A and! B! respectively.

Referring! now! to FIG.!7, a! handpiece 32X for practicing! the! method! of FIG.!6 includes! at! least! one

additional! sensor! (not! shown),! similar! to! above-described! sensor! 41! but! arranged! to! detect! lateral line-crossings. In! such! a! lateral! line-crossing sensor,! apertures! of! the! sensor! would! be! aligned orthogonal! to! those! of! above! described! sensor! 41. This! is! illustrated! in! FIG.! 7! by! apertures! (optical fiber! ends) **78X,!76X,** 80X. Preferably,! there! are! two (a! pair! of)! sensors! for! each! direction! as! illustrated in! FIG. 7 by! the! additional! sensor! apertures. Apertures! for! each! pair! of! sensors! are! parallel! to each! other! and! spaced! apart,! preferably! by! at! least! a width! of! a! line! 46! or! 46X.! This! arrangement! avoids problems! that! would! be! created! by! having! only! one! set of! sensors! for! a! particular! direction! of! travel aligned! over! a! line! in! the! direction! intended! for! the sensor! of! the! opposite! direction.

From! the! above! discussion,! those! skilled! in! the art! will! be! able! to! devise! electronic! processing logic! for! interpreting! information! from! such! a! set! of sensors! without! further! explanation. One! such processing! method,! for! example! may! include, displaying! each! therapeutically-effective,! automatic firing! of! the! laser! as! a! square! on! display! 43! of console! 38,! the! position! of! the! square! corresponding to! its! position! in! grid! 44X! of! FIG.! 6.! This! would provide! an! instant! visual! indication! of! the! existence and! position! of! any! spots! which! had! not! been effectively! treated.

Referring! now! to! FIGS.! 8-il,! in! still! another method! of! operating! apparatus! 30,! a! ruled! strip! 90! is placed,! with! equally-spaced! rulings! 92! thereof uppermost,! on! skin! 48! to! be! treated! (see! FIG.! 8). Rulings! 92! are! preferably! spaced! apart! by! a! distance equal! to! a! linear! dimension! of! the! area! treatable! in a! single! firing! of! the! laser! or! a! sub-multiple! of that! dimension,! for! reasons! discussed! above! with

reference to handpiece 32 of FIG. 2. Rulings 92 may also be arbitrarily spaced by some distance relatively small by comparison with the linear dimension of the area treatable in a single pulse, for example as small as the width of a ruling. This allows detection of many indicia crossings which can enable calculation of increasing or decreasing speed of movement of the handpiece.

A handpiece 32Y, with lens 58 thereof in contact with skin 38, is maintained in contact with strip 90 (see FIG. 11) and moved in a direction indicated by arrows A (see FIG. 8). Tip 34Y of handpiece 32 has its width reduced at its contact end to form steps 94 on each side thereof. Steps 94 preferably have a height just sufficient to allow horizontal surfaces **96** thereof to make contact with strip 90 when tip 34Y is in contact with skin 48 (see FIG. 11).

Handpiece 32Y includes at least one position sensor 41 (light-source and detectors thereof not shown in FIGS. 8-11) including an optical fiber 76 delivering light from the sensor's light-source and optical fibers 78 and 80 for transmitting light to the sensor's detectors. The optical fibers are threaded through handpiece 32Y and are held by a contact block 98 in the above-described alignment and angular relationship of sensor 41 of handpiece 32. Contact block 98 is attached to an extended portion 35 of handpiece 32Y. Extended portion 35 has a width equal to the width of tip 34Y across steps 94. Ends of optical fibers 76, 78 and 80 are held flush with base 102 of block 100 which is flush with horizontal surface **96** of step 94.

Strip 90 is preferably made from a translucent (bulk scattering) material, for example, a fluorocarbon polymer. Rulings 92 are made opaque to

light! from! the! light-source! of! sensor! 41.! It! is! also possible! to! use! lines! or! rulings! drawn! on! any! diffuse reflector,! for! example,! dark! lines! drawn! on! white (bright)! paper! or! white,! (bright)! diffusely-reflective! lines! drawn! on! a! black! (dark)! surface, i.e.,! a! surface! which! absorbs! light! at! the! wavelength emitted! by! light-source! 70.! There! is! no! requirement that! the! rulings! be! transparent! to! light! from! diode-laser! array 50. Crossings! of! rulings! 92! of! strip! 90 are! detected! and! electronically! processed! in! the manner! described! above! with! reference! to! the apparatus! and! method! of FIG. 2. A crossing! can! be detected! as! a! reduction! in! light! detected! by! a detector 72 or! 74,! for! example,! in! the! case! of! dark lines! on! a! bright! background,! or! as! an! increase! in the! detected! light,! for! example in the! case! of! bright lines! on! a! dark! background.

Typically,! the! method! of! FIG.! 8! is! practiced! by an! operator! holding! strip! 90! in! position! on! skin 48 with! one! hand! and! moving! handpiece 32Y with! the! other hand. As! depicted! in! FIGS.! 9-il,! two! position sensors! 41! may! be! provided,! with! apertures! of! one sensor! on! one! side! of! tip 34Y and! apertures! of! the other! sensor! on! the! other! side! of! tip 34Y. Selective activation! of! one! or! the! other! of! the! sensors provides! for! right! or! left! hand! operation! of handpiece 32Y.

It! should! be! noted! here,! that! while! position sensors! 41! are! described! above! with! reference! to! a remote! light-source! and! detectors! optically communicating! with! sensor! apertures! by! means! of optical! fibers,! this! should! not! be! considered! as! a limiting! configuration! for! such! sensors. By! way! of example,! in! a! handpiece! similar! to! handpiece 32Y, a position! sensor,! logically! functioning! as! described above,! may! be! incorporated! in! a! block! of! similar! size

and! similarly! position! to! block! 100,! with! the! light-source! and! detectors! of! the! sensor! incorporated! in! a single! semiconductor! chip.

The! method! of! FIG.! 8,! using! a! separate! guide strip! rather! than! lines! drawn! on! skin! 48,! permits that! a! position! sensor! may! function! by! means! other than! optical. By! way! of! example,! a! guide! strip! may be! provided! with! magnetized! rulings! or! indicia.! This may! be! in! the! form! of! a! preferentially! magnetized strip! of! a! form! similar! to! that! on! credit! cards! and the! like,! or! rulings! in! a! magnetic! medium! on! a! strip of! a! non-magnetic! material.! One! preferred! sensor! for such! indicia! would! include! at! lest! one! and! preferably two! (for! direction! sensing)! magnetic! pickup! heads located! in! a! block! of! similar! size! and! position! to block! 100. The! two! pickup! heads! would! provide! for! a direction-sensing! capability! as! described! above! for sensor! 41. In! another! example,! rulings! or! indicia! 92 may! be! in! the! form! of! depressions! in! (or! protrusions above)! the! upper! surface! of! guide! strip! 90! with! the indicia! being! sensed! by! two! styli! located! in! a! block of! similar! size! and! position! to! block! 100.

One! advantage! of! the! method! of! FIG.! 8,! whether optical,! magnetic! or! mechanical! indicia! are! used,! is that! higher! sensing! resolution! is! possible! compared with! the! sensing! resolution! obtainable! in! the! method of! FIG.! 2.! The! higher! resolution! permits! a! closer spacing! of! indicia,! which! is! of! particular! advantage in! sensing! the! speed! of! movement! of! the! handpiece, and! even! allows! a! determination! of! whether! the! speed of! movement! is! increasing! or! decreasing.

Regarding! speed! of! movement! of! the! handpiece, as! discussed! above,! there! are! two! primary! criteria which! may! determine! a! maximum! possible! speed! of movement! for! the! handpiece.! One! of! these! criteria! is the! maximum! possible! firing! rate! of! the! laser,! the

other! is! the! rate! at! which! chilled! lens! 58! can adequately! cool! skin 48. Should! the! latter! be! the limiting! criterion,! the! limitation! can! be! overcome! by pre-cooling! an! untreated! sub-area! of! skin 48 while! an adjacent! sub-area! of! the! skin! is! being! treated. Referring! to! FIGS.! 9-11,! one! preferred! means! of effecting! such! a! pre-cooling! is! to! provide! a! pre-cooling! plate 104 of! about! the! same! area! as,! and adjacent! to,! lens! 58! and! about! level! with! contact surface! 59! thereof.

Pre-cooling! plate! 104! is! preferably! formed! from a! material! having! a! high! coefficient! of! thermal conductivity! such! as! copper.! If! copper! is! selected, it! is! preferable! that! it! be! coated! or! plated! with! a hard! corrosion-resistant! material,! for! example, nickel! or! rhodium.! In! handpiece 32Y, pre-cooling plate 104 is! completely! cooled! by! attaching! it! in thermal! contact! with! cooling! jacket 62 (not! visible in! FIGS.! 9-11). Those! skilled! in! the! art! may! devise other! arrangements! for! cooling! pre-cooling! plate! 104 without! departing! from! the! spirit! and! scope! of! the present! invention. Provision! of! the! pre-cooling plate! reduces! the! amount! of! cooling! which! must! be provided! by! chilled! lens! 58,! and! can! thus! permit! a speed! of! movement! up! to! the! laser! firing! rate! limit for! apparatus! 30.

Referring! now! to! FIG.! 12! and! FIG.! 13,! still another! automatic! firing! apparatus! and! method! in accordance! with! the! present! invention! includes placing! a! ruled! guide! strip! 91,! on! edge,! in! contact with! skin! to! be! treated,! and! sensing! crossings! of rulings! 92! thereon! using! a! side-looking! position sensor! incorporated! in! a! handpiece! 32W! in! accordance with! the! present! invention.! The! side-looking position! sensor! is! similar! to! above-described sensor! 41! with! the! exception! that! transmitting

aperture 76 and receiving apertures 78 and 80 thereof face in a direction parallel to the plane of skin being treated. Apertures 76, 78 and 80 are located in block 110 attached to a lateral extension 112 of handpiece 32W.

In one preferred example of operation of handpiece 32, guide strip 91 is made from translucent material having opaque rulings 92, and handpiece 32W is moved, with sensor block 110 thereof in contact with guide-strip 91. Line-crossing detection occurs in the manner described above with respect to sensor 41 of handpiece 32. Alternatively, the guide-strip could be made of a reflecting material such as a metal and having a plurality of slots machined therein to define the rulings. In this case, a drop in detected light intensity would correspond to a line crossing.

Two position sensors with apertures thereof on opposite sides of handpiece 32W may be individually, selectively activated to provide for right or left hand operation of the handpiece as discussed above with reference to handpiece 32Y. Sensing methods are not limited to optical methods as described but may include magnetic and mechanical methods as discussed above.

A particular advantage of the guide strip arrangement of handpiece configuration of FIGS. 12 and 13 is that relative vertical motion (perpendicular to skin 48) between the handpiece and the guide strip is possible while still maintaining sensor apertures 76, 78 and 80 in contact with the ruled surface of the guide strip. This is particularly advantageous when treating skin of a strongly contoured body member such as a knee. Adding an additional sensor 41R on one or both sides of handpiece 32W (see FIG. 12) provides that rotary

motion! of! the! handpiece,! in! a! direction! indicated! by arrows! E,! can! be! detected.! This! can! provide! an operator! with! a! warning! should! the! handpiece! be inadvertently! inclined! in! direction! E! to! a! degree which! would! compromise! proper! therapeutic! treatment.

Referring! now! to! FIG.! 14,! FIG.! 15,! FIGS.! 15A-D and! FIG.! 16,! another! handpiece! 32R! in! accordance! with the! present! invention! is! configured! for! automatic firing! without! the! need! for! a! separate! guide-strip! or markings! ruled! on! skin! to! be! treated.! Handpiece! 32R includes! a! wheel! or! roller! 120! which! rotates! about! an axle! 122! extending! from! tip! 34R! of! the! handpiece! (see FIG.! 16).

Roller! 120! is! arranged! to! make! contact! with skin! 48! being! treated! when! lens! 58! of! the! handpiece makes! contact! with! the! skin.! Moving! the! handpiece! in the! (longitudinal)! direction! indicated! by! arrows! A causes! roller! 120! to! rotate.! Roller! 120! includes radial! markings! or! indicia! 124! on! the! side! thereof facing! handpiece! 32R.! Indicia! 124! have! equal! angular spacing. Handpiece! 32R! includes! a! position! sensor! 41 having! side-looking! apertures! 76,! 78! and! 80 positioned! to! detect! motion! of! indicia! 124! in! the manner! described! above! in! which! similar! sensors detect! motion! of! a! handpiece! over! fixed! indicia.

The! angular! spacing! of! indicia! 124! may! be selected! such! that! peripheral! spacing! of! the! indicia on! roller! 120! is! equal! to,! or! some! sub-multiple! of, the! length! of! lens! 58.! Sensor! 41! can! thereby! provide signals! for! automatic! firing! and! speed! of! movement calculation! as! described! above. Alternatively,! the spacing! may! be! reduced! to! the! point! where! the! line spacing! is! relatively! small! compared! with! the! length of! the! lens,! for! example,! about! equal! to! a! line! width or! less! such! that.! In! this! case,! with! revolution! of roller! 120,! sensor! 41! generates! a! steam! of! signals

similar! to! those! generated! by! a! conventional! shaft encoder. This! would! allow! automatic! firing! to! be effected! at! any! predetermined! interval! simply! by correspondingly! programming! control! electronics! of console! 38.

Preferably,! rotary! motion! of! roller! 120! is damped! such! that! the! roller! can! not! continue! to rotate! if! contact! thereof! with! skin! 48! is! lost.! This provides! that! signals! from! sensor! 41! can! be! used! to determine! loss! of! contact! of! handpiece! 32R! with skin! 48. As! an! alternative! or! backup,! however, another! sensor! 41C! (see FIGS. 15, FIG.! 15A,! FIG.! 15B, 15C! and! 16)! can! be! provided,! the! purpose! of! which! is only! to! sense! contact,! or! loss! thereof,! with! skin! 48.

Contact! sensor! 41C! is! similar! to! above described! position! sensor! 41! except! for! the arrangement! of! light! delivery! optical! fiber! 76! and light! receiving! fibers! 78! and! 80! in! a! block! 100C! (see FIGS. 15A-B! for! details)! for! holding! the! ends! of! the optical! fibers! in! alignment! with! each! other.! In block! 100C! the! relative! angle! between! the! fibers! is about! the! same! as! for! those! of! above-described sensor! 41! but! with! the! angular! subtense! diverging! at the! distal! ends! of! the! fibers! rather! than! converging. This! is! achieved! by! crossing! the! receiving! fibers! 78 and! 80! in! block! 100C! and! arranging! transmitting fiber! 76! to! bisect! the! angle! between! the! receiving fibers.

A! result! of! this! arrangement! is! that! the! amount of! scattered! light! received! by! the! receiving! fibers is! somewhat! reduced! compared! with! the! arrangement! of sensor! 41. The! possibility! of! receiving! fibers! 78 and! 80! receiving! light! from! optical! fiber! 76! by! any optical! mechanism! other! than! volume! scatter! through skin! 48! is! essentially! eliminated.! Because! of! this,

the! effectiveness! of! sensor! 41C! as! a! skin-contact sensor! is! increased! compared! with! that! of! sensor! 41.

Referring! to! FIG.! 15C,! where! this! arrangement functions! as! a! skin-contact! sensor! only,! it! is possible! to! use! a! sensor! block! 100D! which! includes only! a! sending! fiber! 76! and! a! receiving! fiber! 78. This! allows! a! greater! angular! divergence! between! the sending! and! receiving! fibers.! In! FIG.! 15D! is schematically! depicted! the! output! of! a! detector cooperative! with! a! sensor! head! 100D! when! the! sensor head! (the! distal! tips! of! fibers! 76! and! 78)! is! at distances! of! between! 0.0! and! 3.0! mm! for! surfaces! of opaque! grey! plastic! (curve! F)! light-colored! skin (curve! G)! and! translucent! white! plastic! (curve! H). About! 0.5! milliwatts! (mW)! of! light! at! a! wavelength! of about! 660! nm! is! delivered! from! optical! fiber! 76. Optical! fibers! 76! and! 78! each! have! a! diameter! of 1.0! mm! and! are! inclined! at! 40°! from! vertical,! i.e., with! an! angle! of! 80°! therebetween.! The! tips! of! the optical! fibers! are! laterally! and! longitudinally separated! by! 2.0! mm.! It! can! be! seen! that! there! is essentially! zero! detector! output! from! the! opaque! grey plastic! surface! at! any! distance! up! to! contact.! A similar! result! was! obtained! on! a! rough! (diffusely reflecting)! steel! surface.

For! skin! (skin! of! a! finger! in! this! experiment) and! translucent! plastic,! output! increases! gradually as! the! sensor! approaches! the! surfaces. Applying! a force! of! 10.0! grams! (g)! to! the! sensor! head! on! the skin! surface! caused! the! detector! output! to! rise sharply! from! about! 18.0! to 29.5, indicating! the effectiveness! of! the! sensor! head! as! a! contact! sensor. A! further! increase! in! force! provided! no! significant increase! in! output.! In! practice,! a! threshold! level of! detection! can! be! set! at! the! detector! output! level at! skin! contact.! It! is! a! relatively! simple! matter! to

provide! a! calibration! capability,! via! a! potentiometer or! the! like,! to! adjust! the! threshold! for! different skin! shades. Contact! of! the! sensor! head,! or! lack thereof,! can! then! be! determined! according! to! whether the! detector! output! is! above! or! below! the! set threshold! level.

Referring! now! to! FIG.! 17! and! FIG.! 18,! another handpiece! 32E! in! accordance! with! the! present invention! includes! a! wheel! or! roller! 130.! Roller! 130 is! rotatable! on! an! axle! 132! which! extends! through! a bearing! housing! 134! into! an! extended! portion! 37! of tip! 34E! of! handpiece! 32E.! Axle! 132! engages! a! shaft encoder! 136! located! in! extended! portion! 37! of tip! 34E.

Roller! 130! is! arranged! to! make! contact! with skin! 48! being! treated! when! lens! 58! of! the! handpiece makes! contact! with! the! skin.! Moving! the! handpiece! in the! (longitudinal)! direction! indicated! by! arrows! A causes! roller! 130! to! rotate.! Rotation! of! roller! 130 is! monitored! by! shaft! encoder! 136.! Signals! from shaft! encoder! 136! representative! of! the! angular position! or! degree! of! rotation! of! roller! 130! are transmitted! to! control! electronics! in! control console! 38! (see! FIG.! 1)! and! used! for! triggering automatic! firing! and! computing! speed! of! motion! of! the roller. Making! or! breaking! contact! with! skin! 48! by tip **34E** of! handpiece! 32E! can! be! detected! by! the control! electronics! detecting! respectively! initiation and! termination! of! rotation! of! roller! 130! via! signals from! shaft! encoder! 136.! Alternatively! or additionally,! an! optical! skin! contact! sensor! of! the type! described! above! with! reference! to! handpiece! 32R may! be! provided.

Referring! now! to! FIG.! 19,! FIG.! 20! and! FIG.! 21, another! handpiece! 32H! in! accordance! with! the! present invention! is! illustrated. Handpiece! 32H! includes! a

detachable! housing! 121! (shown! in! phantom! in! FIG.! 21) which! attaches! to! tip! 34! of! the! handpiece. Detachable! housing! 121! includes! a! wheel! or! roller! 123 arranged! to! engage! skin! 48! being! treated! when! lens! 58 of! tip! 34! is! placed! in! contact! with! the! skin.

Roller! 123! includes! a! series! of! equally-spaced, parallel! (paraxial)! longitudinal! rulings! 125! around! a cylindrical! surface! of! the! roller! (see! FIG.! 20).! The spacing! of! the! rulings! is! preferably! equal! to! or! some sub-multiple! of! the! length! of! lens! 58! for! reasons discussed-above,! for! example,! with! reference! to handpiece! 32R. Alternatively! the! lines! may! be! set sufficiently! close! together! that! the! roller! and detector! function! in! the! manner! of! a! conventional shaft! encoder! as! discussed! above.

A! sensor! block! 127! including! distal! ends! of optical! fibers! 76,! 78! and! 80! of! a! position! sensor! 41 is! located! on! tip 34 of! handpiece! 32H! (see! FIG.! 21). Here,! the! distal! ends! of! the! fibers! are! arranged! in! a. vertically-oriented! line! such! that! the! position sensor! can! detect! the! passage! of! rulings! 125! of roller! 123! as! the! roller! rotates! responsive! to! motion of! the! handpiece! over! skin! 48.! From! the! detection! of rulings,! the! position! of! handpiece! 32H! on! skin! 48! can be! determined! as! discussed! above.

Referring! to! FIG.! 20A,! an! alternative roller! 123A! for! handpiece! 32H! is! illustrated. Roller! 123A! comprises! two! coaxial! cylindrical portions! 129! and! bounding! a! cylindrical! portion! 131 coaxial! therewith! but! having! a! lesser! diameter! than cylindrical! portions! 129. Here,! paraxial! rulings! 125 are! made! on! cylindrical! portion 131. This! helps minimize! contact! with! the! rulings! on! contacting skin! 48! when! roller! 123A! contacts! skin! 48! via cylindrical! portions! 129! thereof. Contact! of rulings! 125! with! skin! 48! could! progressively! lead! to

contamination! with! skin! grease,! skin! debris! and! the like. Such! contamination! could! lead! to! errors! in! the accuracy! of! position! determination! by! position sensor! 41.

Sensor! handpiece! 32H! is! described! above! as including! a! position! sensor! 41! having! a! light-source and! detectors! thereof! located! in! the! body! of! the handpiece! and! connected! to! a! sensor! block! by! optical fibers. Those! skilled! in! the! art! will! recognize however! that! a! similarly! functioning! sensor! head could! be! positioned! in! detachable! housing! 121! without departing! from! the! spirit! and! scope! of! the! present invention. In! fact! it! is! possible! to! locate! all components! of! a! position! detector! in! detachable housing! 121,! requiring! only! an! electrical! connection with! the! body! of! the! handpiece! for! power! and! data communication.

It! is! pointed! out! here! that! indicia! on! any above-described! rollers! may! be! dark! lines! on! a! bright. background! or! bright! lines! on! a! dark! background. Alternatively,! the! indicia! may! be! fluorescent,! or! may be! magnetic! if! sensor! 41! is! replaced! with! a! magnetic pick-up! arrangement.

Referring! now! to! FIG.! 22,! another! handpiece! 32T in! accordance! with! the! present! invention! includes! a transponder! 140! and! a! receiver! 142.! Preferably, transponder! 140! is! an! ultrasonic! emitter! and receiver 142 is! an! ultrasonic! detector. Transponder 140 sends! a! signal-pulse! (dashed line! 144)! to! a! screen! or! wall 146 located! proximate! a patient! 148! on! whose! back! skin! 48! is! being! treated. Here,! screen 146 is! shown! mounted! on! a! table! 150! on which! patient! 148! is! lying! in! a! face-down! position.

Receiver 142 receives! an! echo! (a! return-pulse) of! the! signal-pulse! sent! by! transponder! 140! (dashed line! 152)! from! screen! 146.! Control! electronics! of

console! 38,! connected! to! transducer! 140! and receiver! 142! record! the! time! of! sending! signal-pulse! 144! and! time! of! receiving! echo! 152 corresponding! thereto! and! determine! a! time! difference between! the! sending! and! receiving.! The! time difference! between! the! sending! of! signal-pulse! 144 and! the! receiving! of! echo! 152! provides! a! measure! of the! position! of! handpiece! 32T! with! respect! to screen! 146! and,! accordingly,! with! respect! to patient! 148! as! the! handpiece! is! moved! in! a longitudinal! direction! indicted! by! arrows! A. These position! measurements! are! used! by! control! electronics of! console! 38! to! automatically! trigger! firing! of! the laser! at! equal! position! increments! of! handpiece! 32, and,! optionally,! to! monitor! the! speed! of! motion! of handpiece! 32T! as! discussed! above! with! reference! to other! embodiments! of! the! apparatus! and! method! of! the present! invention.

It! should! be! noted! here! that! the! treatment illustrated! in! FIG.! 22! and! the! position! of! screen 146 with! respect! to! patient 148 are! merely! exemplary. Those! skilled! in! the! art! may! devise! other! screen locations! adapted! to! other! treatments! without departing! from! the! spirit! and! scope! of! the! present invention.

It! should! also! be! noted! that! while! an! ultrasonic emitter! and! receivers! are! preferred! in! the! above described! embodiment! of! the! present! invention,! the operating! principles! of! this! embodiment! are applicable! if! transponder 140 (and! corresponding receivers 142) rely! on! sending! and! detection! of signals! other! than! ultrasonic! signals.! By! way! of example,! these! may! be! optical! signals! (pulses) generated! by! a! laser,! forming! in! effect! a! laser rangefinder. The! laser! may! be! located! in,! or! on, handpiece! 32T,! or! may! be! remote! therefrom! with

radiation from the laser being delivered to transponder 140 by an optical fiber. The signals may also be radar signals (pulses) with transponder 140 being a miniature, (for example incorporated in a semiconductor chip) radar transmitter. In the case of optical or radar signals, electronic processing of the signals may prove to be more complex than for ultrasonic signals, because of the relatively short distances traversed by signal pulses and, correspondingly, the relatively very short time between sending and detection thereof.

Referring now to FIG. 23, another handpiece 32D in accordance with the present invention includes a transponder 160. Preferably, transponder 160 is an ultrasonic emitter. Transponder 160 sends a signal-pulse (dashed lines 162) radiating therefrom in a diverging manner to three receivers 164, preferably ultrasonic detectors incorporated in a video display unit (VDU) 166 having a display 168. Here, VDU 166 is shown positioned proximate table 150 on which patient 148, on whose back skin 48 is being treated, is lying in a face-down position.

In one example of signal processing for the arrangement of handpiece 32D and receivers associated therewith, for each signal-pulse the difference in arrival time at each the receivers is recorded. Based on this difference in arrival time, and on the spacing of the receivers, control electronics associated with the transponder and receivers determine, by triangulation, a position in longitudinal direction A and lateral direction B for transponder 160 relative to a plane in which the receivers are located. Here the plane is of the front of VDU 166. This position measurement is used by control electronics of console 38 to automatically trigger firing of the laser depending on its lateral

and longitudinal position. A visual record of the firings is presented on display 168.

It should be noted here that, in theory at least, only two detectors are necessary to provide two dimensional position location for the handpiece. Providing three detectors can increase the accuracy of two dimensional position location and also provide information on position in a third (perpendicular to the general plane of the skin) direction. This information can be useful if a contoured area of skin, for example, a knee, is being treated.

In one example of operation of handpiece 32D, point 170P on patient 148 designates the lower left-hand corner (origin) of an area of skin 48 to be treated. This area is considered to be divided into a series on sub-areas equal in dimension to lens 58 of handpiece 32D. Point 170D on display 168 is electronically arranged to represent point 170P on patient 48.

The instantaneous position of handpiece 32D relative to point 170P is indicated on display 168 by a square "cursor" 169 having dimensions representing the area treatable in a single firing of the laser. Treatment is initiated by placing tip 34 of handpiece 32D in contact with skin 48 of patient 148 and activating trigger 36 of the handpiece to begin automatic firing.

Each successful firing is recorded on display 169 as a solid square, thereby providing a direct indication of progress of then treatment and of any areas such as an area 171 which may have been "missed". Control electronics may also be arranged to store an electronic map of successful firings. The stored electronic map can be used by the control electronics to automatically fire the laser when the position detection system senses that the handpiece

tip! is! contacting! the! skin! in! a! missed! area.! The stored! electronic! map! can! be! also! be! used! by! the control! electronics! to! prevent! manual! firing! of! the laser! if! the! handpiece! tip! is! in! contact! with! the skin! in! an! area! that! has! already! been! successfully treated.

It! should! be! noted! here! that! receivers **164** are shown! integrated! into **VDU! 166** as! one! convenient location! for! the! detectors.! Receivers 164 may! also be! located! remote! from **VDU! 166** and! supported! on! a separate! frame! and! locations! may! be! varied! according a! specific! treatment.! Such! locations! may! be! selected and! varied! without! departing! from! the! spirit! and scope! of! the! present! invention.

While! preferred! embodiments! of! the! present invention! are! described! above! with! reference! tracking motion! of! a! handpiece! in! which! a! laser! source! is located,! the! present! invention! is! not! limited! to! use with! such! a! handpiece.! Principles! of! the! application are! also! applicable! to! a! handpiece! which! delivers radiation! received! from! a! remotely! located! source! of laser-radiation. Such! a! handpiece,! for! example,! may receive! radiation! from! the! remote! source! via! an optical! fiber! of! bundle! of! optical! fibers! or! via! a hollow! articulated! arm.! Further,! principles! of! the present! invention! are! equally! applicable! if! treatment does! not! require! that! the! tip! or! delivery! aperture! of the! handpiece! is! in! contact! with! skin! being! treated. By! way! of! example,! the! tip! may! include! a! lens! for shaping! or! focussing! the! delivered! radiation! and! may be! spaced! at! a! relatively! short! distance! (about! one or! two! centimeters)! from! the! skin! with! spacing! being maintained! by! an! open! jig! in! contact! with! the! skin.

It! should! also! be! noted! that! automatic! firing! in accordance! with! the! present! invention! has! been described! with! reference! to! controlling! firing! such

that! sub-areas! treated! in! a! single! filing! are! "tiled" together! more! or! less! contiguously! to! cover! a! total area! to! be! treated,! any! of! the! above! described embodiments! to! covering! an! area! by! overlapping treated! sub-areas! in! a! predetermined! pattern.! By! way of! example,! each! treated! (in! a! single! firing)! sub-area! may! overlap! the! previously! treated! sub-area! by half! the! length! of! the! sub-area.! This! may! be! done for! example! to! avoid! the! possibility! of! any! narrow untreated! areas! being! left! between! treated! sub-areas.

Generally,! the! present! invention! is! described and! depicted! herein! in! terms! of! a! preferred! and! other embodiments. The! invention,! however,! is! not! limited by! those! embodiments! described! and! depicted. Rather, the! invention! is! limited! only! by! the! claims! appended hereto.

WHAT IS! CLAIMED! IS:

1. A! method! of! treating! an! area! of! skin! with! a laser! by! delivering! a! series! of! laser-radiation pulses! to! the! skin,! each! of! the! laser! pulses! treating a! sub-area! of! the! area! to! be! treated,! the! method comprising! the! steps! of:

(a) providing! a! laser! which,! on! being! fired, generates! a! pulse! of! laser-radiation;

(b) providing! a! handpiece! for! delivering! a! pulse of! laser-radiation! from! said! laser! to! the! skin! being treated;

(c) while! moving! the! handpiece! over! the! skin being! treated,! electronically! determining! the location! of! said! handpiece! in! the! area! of! skin! being treated;! and

(d) automatically! firing! the! laser! when! said electronically! determined! location! corresponds! to! a sub-area! to! be! treated.

2. The! method! of! claim! 1! wherein! said! location determining! step! (c)! comprises! the! steps! of! (i) providing! a! plurality! of! regularly! spaced! indicia! on or! adjacent! the! area! of! skin! being! treated! (ii) providing! at! least! one! sensor! on! the! handpiece! said sensor! arranged! to! detect! passage! of! the! handpiece! by one! or! more! of! said! indicia! as! the! handpiece! is! moved over! the! skin! being! treated! and! wherein! in! step! (d) said! automatic! firing! is! triggered! by! the! passage! of the! handpiece! by! one! or! more! of! said! indicia.

3. The! method! of! claim! 2,! wherein! said! indicia are! one! of! graphic! indicia,! magnetic! indicia,! and mechanical! indicia.

4. The! method! of! claim 3 wherein! said! indicia are! graphic! indicia.

5. The method of claim 4, wherein said sensor includes a light-source arranged to direct light onto the skin being treated such that the thus directed light is scattered by the skin being treated; wherein said sensor includes one or more light detectors arranged to detect said scattered light; wherein said graphic indicia are equally-spaced parallel lines drawn on the area of skin being treated in a medium which is at least partially opaque to the wavelength of light emitted by said light-source and substantially transparent to the wavelength of said pulse of laser radiation; and wherein passage of the handpiece by any one of said indicia results in a reduction in said scattered light detected by said at least one detector, said reduction in scattered light indicating that one of said indicia has been passed.

6. The method of claim 4, wherein said graphic indicia are equally-spaced parallel lines drawn on a strip of material placed on or adjacent to the area of skin being treated; wherein said sensor includes a light-source arranged to direct light onto the strip such that the thus directed light is scattered by the strip; wherein said sensor includes one or more light detectors arranged to detect said scattered light; wherein said strip is diffusely reflective at the wavelength of light emitted by said light-source for said directed light and said lines are drawn in a medium which is absorbent at the wavelength of light emitted by said light-source; and wherein passage of the handpiece by any one of said indicia results in a reduction in said scattered light detected by said at least one detector, said reduction in scattered light indicating that one of said indicia has been passed.

7. The method of claim 4, wherein said graphic indicia are equally-spaced parallel lines drawn on a strip of material placed on or adjacent to the area of skin being treated; wherein said sensor includes a light-source arranged to direct light onto the strip; wherein said strip is absorbent at the wavelength of light emitted by said light-source and said lines are drawn in a medium which is diffusely reflective at the wavelength of light emitted by said light-source; wherein said sensor includes one or more light detectors arranged to detect directed light diffusely reflected by said lines; and wherein passage of the handpiece by any one of said indicia results in an increase in light detected by said at least one detector, said increase in detected light indicating that one of said indicia has been passed.

8. The method of claim 4, wherein said graphic indicia are equally-spaced parallel lines drawn on a strip of material placed on or adjacent to the area of skin being treated; wherein said sensor includes a light-source arranged to direct light onto the strip; wherein said lines are drawn in a medium which is fluorescent on irradiation with light emitted by said light-source; wherein said sensor includes one or more light detectors arranged to said fluorescence; and wherein passage of the handpiece by any one of said indicia results in increase in light detected by said at least one detector, said increase in detected light indicating that one of said indicia has been passed.

9. The method of claim 3 wherein said indicia are magnetic indicia

10. The method of claim 3 wherein said indicia are mechanical indicia.

11. The method of claim 2 wherein said indicia are spaced apart by a distance equal to one of a linear dimension of the sub-area irradiated by said laser pulse; a distance equal to a sub-multiple of a linear dimension of the sub-area irradiated by said laser pulse; and a distance relatively small compared with a linear dimension of the sub-area irradiated by said laser pulse.

12. The method of claim 1 wherein said location determining step (c) comprises the steps of (i) providing a roller on the handpiece, said roller arranged to contact the skin being treated and rotate in response to the handpiece being moved over the skin being treated, and said roller having a plurality of regularly spaced indicia thereon (ii) providing at least one sensor on the handpiece said sensor arranged to detect passage by said sensor of one or more of said indicia as said roller rotates and wherein in step (d) said automatic firing is triggered by the passage by said sensor of one or more of said indicia.

13. The method of claim 12, wherein said indicia are radially extending lines on a side of said roller.

14. The method of claim 13, wherein said indicia are spaced apart at the periphery of said roller by a distance equal to one of a linear dimension of the sub-area irradiated by said laser pulse; a distance equal to a sub-multiple of a linear dimension of the sub-area irradiated by said laser

pulse;! and! a! distance! relatively! small! compared! with a! linear! dimension! of! the! sub-area! irradiated! by! said laser! pulse.

15. The! method! of! claim! 12! wherein! said! indicia are! longitudinally! extending! lines! on! a! first cylindrical! surface! of! said! roller.

16. The! method! of! claim! 15,! wherein! said indicia! are! spaced! apart! at! the! periphery! of! said roller! by! a! distance! equal! to! one! of! a! linear dimension! of! the! sub-area! irradiated! by! said! laser pulse;! a! distance! equal! to! a! sub-multiple! of! a! linear dimension! of! the! sub-area! irradiated! by! said! laser pulse;! and! a! distance! relatively! small! compared! with a! linear! dimension! of! the! sub-area! irradiated! by! said laser! pulse.

17. The! method! of! claim! 15! wherein! said! first cylindrical! surface! of! said! roller! is! a! skin contacting! surface! of! said! roller.

18. The! method! of! claim! 15! wherein! said! roller has! a! second! cylindrical! surface! for! contacting! the skin,! and! first! cylindrical! surface! has! a! smaller diameter! than! the! diameter! of! said! second! cylindrical surface.

19. The! method! of! claim! 1! wherein! said! location determining! step! (c)! comprises! the! steps! of! (i) providing! a! roller! on! the! handpiece,! said! roller arranged! to! contact! the! skin! being! treated! and! rotate in! response! to! the! handpiece! being! moved! over! the skin! being! treated! said! roller! being! axially connected! to! a! shaft! encoder! said! shaft! encoder

providing! signals! used! for! said! electronic! location determining.

20. The! method! of! claim! 1! wherein! said! location determining! step! (c)! comprises! the! steps! of! (i) providing! a! screen! adjacent! the! skin! being! treated (ii) providing! a! transponder! on! the! handpiece,! said transponder! arranged! to! emit! a! regular! train! of signal-pulses! toward! said! screen! such! that! said signal-pulses! are! incident! thereon! and! a! return-pulse corresponding! to! each! of! said! incident! signal-pulses returns! to! the! handpiece! (iii)! providing! a! receiver on! said! handpiece! for! receiving! said! return! pulses (iv) determining! an! elapsed! time! between! emitting! a said! signal-pulse! and! receiving! a! said! corresponding return-pulse,! said! elapsed! time! being! representative of! said! location! of! said! handpiece.

21. The! method! of! claim! 20! wherein! said! signal-pulses! are! ultrasonic! pulses.

22. The! method! of! claim! 20! wherein! said! signal-pulses! are! optical! pulses.

23. The! method! of! claim! 20! wherein! said! signal-pulses! are! radar! pulses.

24. The! method! of! claim! 1! wherein! said! location determining! step! (c)! comprises! the! steps! of! (i) providing! a! transponder! on! the! handpiece,! said transponder! arranged! to! emit! a! regular! train! of signal-pulses! each! thereof! in! diverging! beam! (ii) providing! at! least! two! spaced-apart! receivers! located in! a! position! remote! from! said! handpiece,! within! the divergence! of! said! beam,! for! receiving! said! signal pulses! (iii)! based! on! the! spacing! of! said! receivers

and an arrival time of said signal pulses at said receivers determining said location of said handpiece in at least length and width dimensions of said area of skin to be treated.

25. The method of claim 24 wherein said signal-pulses are one of ultrasonic pulses, optical pulses, or radar pulses.

26. The method of claim 25 wherein said signal pulses are ultrasonic pulses.

27. The method of claim 24, wherein said area of skin to be treated is contoured and said three spaced apart receivers are provided, and said location of said handpiece in said area of skin to be treated is determined in length width and height dimensions.

28. The method of claim 25 wherein said signal-pulses are one of ultrasonic pulses, optical pulses, .. or radar pulses.

29. A method of treating an area of skin with a laser by delivering a series of laser-radiation pulses to the skin, each of the laser pulses treating a sub-area of the area to be treated, the method comprising the steps of:

(a) providing a laser which, on being fired, generates a pulse of laser-radiation;

(b) providing a handpiece for delivering a pulse of laser-radiation from said laser to the skin being treated;

(c) while moving the handpiece over the skin being treated, electronically determining a location of said handpiece in the area of skin being treated

said! location! determining! including! (i)! providing! a plurality! of! regularly! spaced! indicia! on! or! adjacent the! area! of! skin! being! treated,! and! (ii)! providing! at least! one! sensor! on! the! handpiece! said! sensor arranged! to! detect! passage! of! the! handpiece! by! one! or more! of! said! indicia! as! the! handpiece! is! moved! over the! skin! being! treated;! and

(d) automatically! firing! the! laser! on! detection of! passage! of! the! handpiece! by! one! or! more! of! said indicia.

30. The! method! of! claim! 29! wherein! said! indicia are! spaced! apart! by! a! distance! equal! to! one! of! a linear! dimension! of! the! sub-area! irradiated! by! said laser! pulse;! a! distance! equal! to! a! sub-multiple! of! a linear! dimension! of! the! sub-area! irradiated! by! said laser! pulse;! and! a! distance! relatively! small! compared with! a! linear! dimension! of! the! sub-area! irradiated! by said! laser! pulse.

31. The! method! of! claim! 30! wherein! said! indicia are! provided! by! a! grid! of! parallel! lines! drawn! on! the area! of! skin! to! be! treated.

32. The! method! of! claim! 30! wherein! said! indicia are! provided! by! first! and! second! grids! of! parallel lines! drawn! on! the! area! of! skin! to! be! treated,! said second! grid! being! arranged! orthogonal! to! said! first grid,! and! wherein! said! handpiece! is! provided! with! at least! first! and! second! sensors,! said! first! and! second sensors! for! detecting! passage! of! said! handpiece! by lines! in! respectively! said! first! and! second! grids.

33. The! method! of! claim! 30! wherein! said! indicia are! provided! by! a! parallel! rulings! on! a! strip! of

material! placed! on! or! adjacent! the! area! of! skin! to! be treated.

34. A! method! of! treating! an! area! of! skin! with! a laser! by! delivering! a! series! of! laser-radiation pulses! to! the! skin,! each! of! the! laser! pulses! treating a! sub-area! of! the! area! to! be! treated,! the! method comprising! the! steps! of:

(a) providing! a! laser! which,! on! being! fired, generates! a! pulse! of! laser-radiation;

(b) providing! a! handpiece! for! delivering! a! pulse of! laser-radiation! from! said! laser! to! the! skin! being treated;

(c) while! moving! the! handpiece! over! the! skin being! treated,! electronically! determining! a! location of! said! handpiece! in! the! area! of! skin! being! treated said! location! determining! including! (i)! providing! a roller! on! the! handpiece,! said! roller! arranged! to contact! the! skin! being! treated! and! rotate! in! response to! the! handpiece! being! moved! over! the! skin! being treated,! and! said! roller! having! a! plurality! of regularly! spaced! indicia! thereon! and! (ii)! providing at! least! one! sensor! on! the! handpiece,! said! sensor arranged! to! detect! passage! by! said! sensor! of! one! or more! of! said! indicia! as! said! roller! rotates;! and

(d) automatically! firing! the! laser! on! detection of! passage! by! the! sensor! of! one! or! more! of! said indicia.

35. The! method! of! claim! 34,! wherein! said indicia! are! radially-extending! lines! on! a! side! of said! roller.

36. The! method! of! claim! 35,! wherein! said indicia! are! spaced! apart! at! the! periphery! of! said roller! by! a! distance! equal! to! one! of! a! linear

dimension! of! the! sub-area! irradiated! by! said! laser pulse;! a! distance! equal! to! a! sub-multiple! of! a! linear dimension! of! the! sub-area! irradiated! by! said! laser pulse;! and! a! distance! relatively! small! compared! with a! linear! dimension! of! the! sub-area! irradiated! by! said laser! pulse.

37. The! method! of! claim! 36! wherein! said! indicia are! longitudinally-extending! lines! on! a! first cylindrical! surface! of! said! roller.

38. The! method! of! claim! 37,! wherein! said indicia! are! spaced! apart! at! the! periphery! of! said roller! by! a! distance! equal! to! one! of! a! linear dimension! of! the! sub-area! irradiated! by! said! laser pulse;! a! distance! equal! to! a! sub-multiple! of! a! linear dimension! of! the! sub-area! irradiated! by! said! laser pulse;! and! a! distance! relatively! small! compared! with a! linear! dimension! of! the! sub-area! irradiated! by! said laser! pulse.

39. A! method! of! treating! an! area! of! skin! with! a laser! by! delivering! a! series! of! laser-radiation pulses! to! the! skin,! each! of! the! laser! pulses! treating a! sub-area! of! the! area! to! be! treated,! the! method comprising! the! steps! of:

(a) providing! a! laser! which,! on! being! fired, generates! a! pulse! of! laser-radiation;

(b) providing! a! handpiece! for! delivering! a! pulse of! laser-radiation! from! said! laser! to! the! skin! being treated;

(c) while! moving! the! handpiece! over! the! skin being! treated,! electronically! determining! a! location of! said! handpiece! in! the! area! of! skin! being! treated said! location! determining! including! (i)! providing! a screen! adjacent! the! skin! being! treated,! (ii)

providing a transponder on the handpiece, said transponder arranged to emit a regular train of signal-pulses toward said screen such that said signal-pulses are incident thereon and a return-pulse corresponding to each of said incident signal-pulses returns to the handpiece, (iii) providing a receiver on said handpiece for receiving said return pulses, and (iv) determining an elapsed time between emitting a said signal-pulse and receiving a said corresponding return-pulse, said elapsed time being representative of said location of said handpiece; and

(d) automatically firing the laser when said electronically determined location corresponds to a sub-area to be treated.

40. A method of treating an area of skin with a laser by delivering a series of laser-radiation pulses to the skin, each of the laser pulses treating a sub-area of the area to be treated, the method comprising the steps of:

(a) providing a laser which, on being fired, generates a pulse of laser-radiation;

(b) providing a handpiece for delivering a pulse of laser-radiation from said laser to the skin being treated;

(c) while moving the handpiece over the skin being treated, electronically determining a location of said handpiece in the area of skin being treated said location determining including (i) providing a transponder on the handpiece, said transponder arranged to emit a regular train of signal-pulses each thereof in diverging beam, (ii) providing at least two spaced-apart receivers located in a position remote from said handpiece, within the divergence of said beam, for receiving said signal

pulses,! and! (iii)! based! on! the! spacing! of! said receivers! and! an! arrival! time! of! said! signal! pulses at! said! receivers! determining! said! location! of! said handpiece! in! at! least! length! and! width! dimensions! of said! area! of! skin! to! be! treated;! and

(d) automatically! firing! the! laser! when! said electronically! determined! location! corresponds! to! a sub-area! to! be! treated.

41. The! method! of! claim! 40,! wherein! said! area of! skin! to! be! treated! is! contoured! and! three! spaced-apart! receivers! are! provided,! and! said! location! of said! handpiece! in! said! area! of! skin! to! be! treated! is determined! in! length! width! and! height! dimensions.

42. A! method! of! treating! an! area! of! skin! with! a laser! by! delivering! a! series! of! pulses! of electromagnetic! radiation! to! the! skin,! each! of! the electromagnetic! radiation! pulses! treating! a! sub-area-of! the! area! to! be! treated,! the! method! comprising! the steps! of:

(a) providing! a! source! of! electromagnetic radiation! which,! on! being! fired,! generates! a! pulse! of electromagnetic! radiation;

(b) providing! a! handpiece! for! delivering! a! pulse of! electromagnetic! radiation! from! said! source! thereof to! the! skin! being! treated;

(c) while! moving! the! handpiece! over! the! skin being! treated,! electronically! determining! the location! of! said! handpiece! in! the! area! of! skin! being treated;! and

(d) automatically! firing! the! source! of electromagnetic! radiation! when! said! electronically determined! location! corresponds! to! a! sub-area! to! be treated.

43. In an apparatus for skin treatment using electromagnetic radiation, the apparatus including a source of the electromagnetic radiation and a handpiece cooperative therewith for delivering the electromagnetic radiation to skin being treated, the electromagnetic radiation being delivered by the handpiece through a transparent applicator therein, the applicator being in contact with the skin being treated during treatment, a method of sensing that the applicator is in contact with the skin, the method comprising the steps of:

(a) providing a light-source having an exit-aperture thereof on the handpiece, said exit-aperture configured to be in contact with the skin being treated when the applicator is in contact with the skin being treated;

(b) delivering light from said light-source via said exit-aperture thereof such that, when the applicator is one of proximate the skin or in contact with the skin, light delivered from said exit-aperture is transported laterally through the skin via volume scattering of said light;

(c) providing a detector having a receiving-aperture on said handpiece proximate said light-source exit-aperture;

(d) monitoring the output of said detector; and

(e) interpreting said monitored detector-output as an indication that the applicator of said handpiece has made or lost contact with the skin being treated.

44. A laser system for treating tissue comprising:

a laser for generating laser light;

a! delivery! device! including! a! manually movable! handpiece! for! delivering! the! laser! light to! the! tissue;

a! sensor! associated! with! the! handpiece! for monitoring! the! movement! of! the! handpiece! with respect! to! the! tissue,! said! sensor! generating output! signals;! and

a! processor! for! controlling! the! triggering of! the! laser! in! response! to! the! receipt! of! the output! signals! in! a! manner! to! facilitate! uniform treatment! of! the! tissue! over! a! large! area! with the! laser! light.

45. A! laser! system! as! recited! in! claim! 44 further! including! ruled! indicia! spatially! associated with! the! tissue! to! be! treated! and! wherein! the! sensor is! mounted! on! the! handpiece! in! a! manner! to! detect said! indicia! as! the! handpiece! is! moved! thereby.

46. A! laser! system! as! recited! in! claim! 45 wherein! said! indicia! are! formed! by! one! of:

a) markings! directly! on! the! tissue! to! be treated;! and

b) markings! on! a! rule! located! proximate! the surface! of! the! skin.

47. A! laser! system! is! recited! in! claim! 46 wherein! said! indicia! are! graphic! and! said! sensor detects! the! indicia! optically.

48. A! laser! system! as! recited! in! claim! 47 wherein! said! sensor! includes! a! light! source! aimed! at said! indicia,! said! sensor! further! including! a photodetector! configured! to! monitor! changes! in! light caused! by! the! presence! of! the! indicia.

49. A laser system as recited in claim 44 wherein said sensor includes a wheel rotatably mounted to the handpiece, said wheel rotating in response to the movement of the handpiece across the tissue and wherein said sensor monitors the rotation of the wheel.

50. A laser system as recited in claim 49 wherein the wheel includes ruled indicia which are monitored by the sensor.

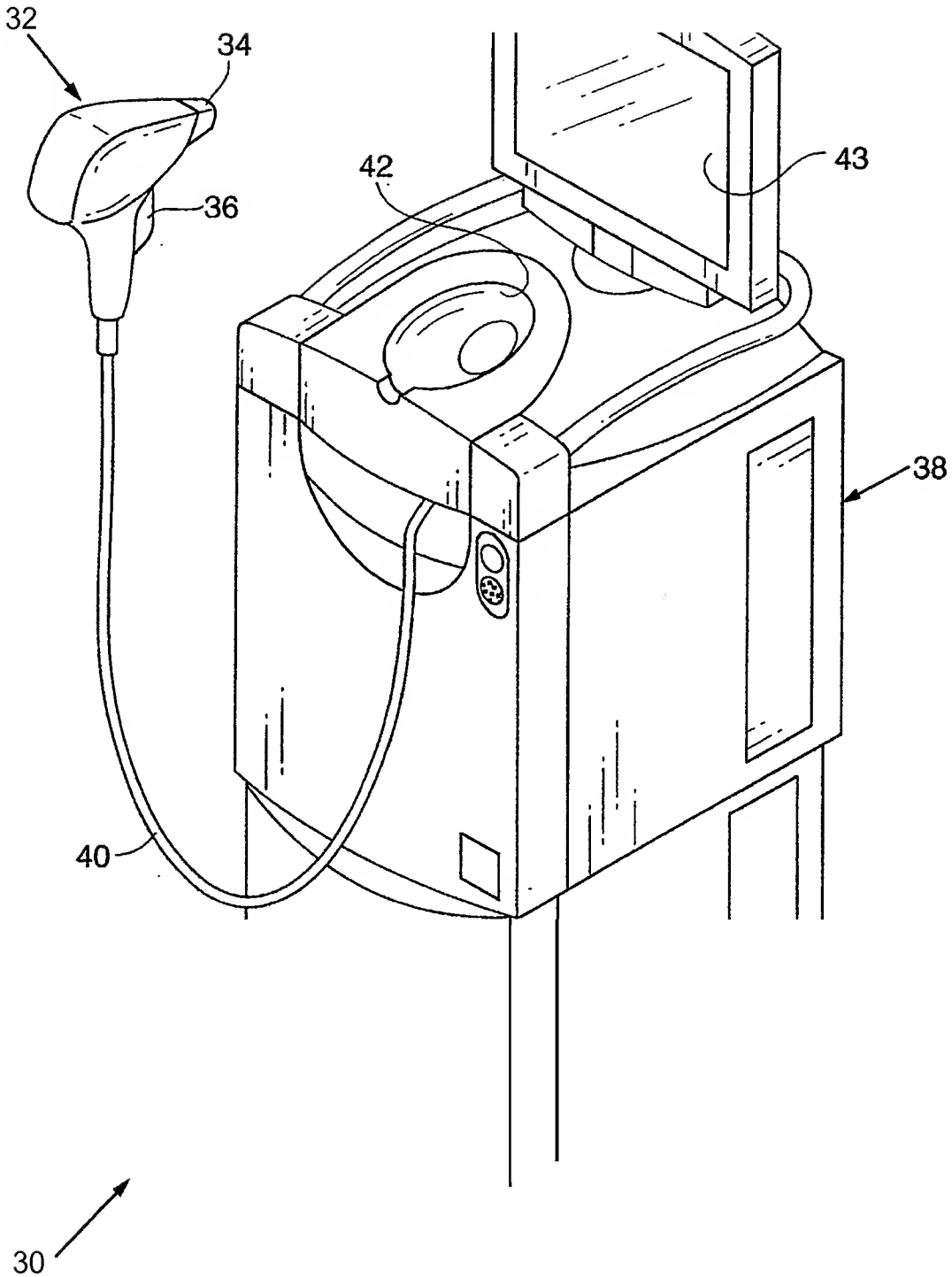


FIG. 1

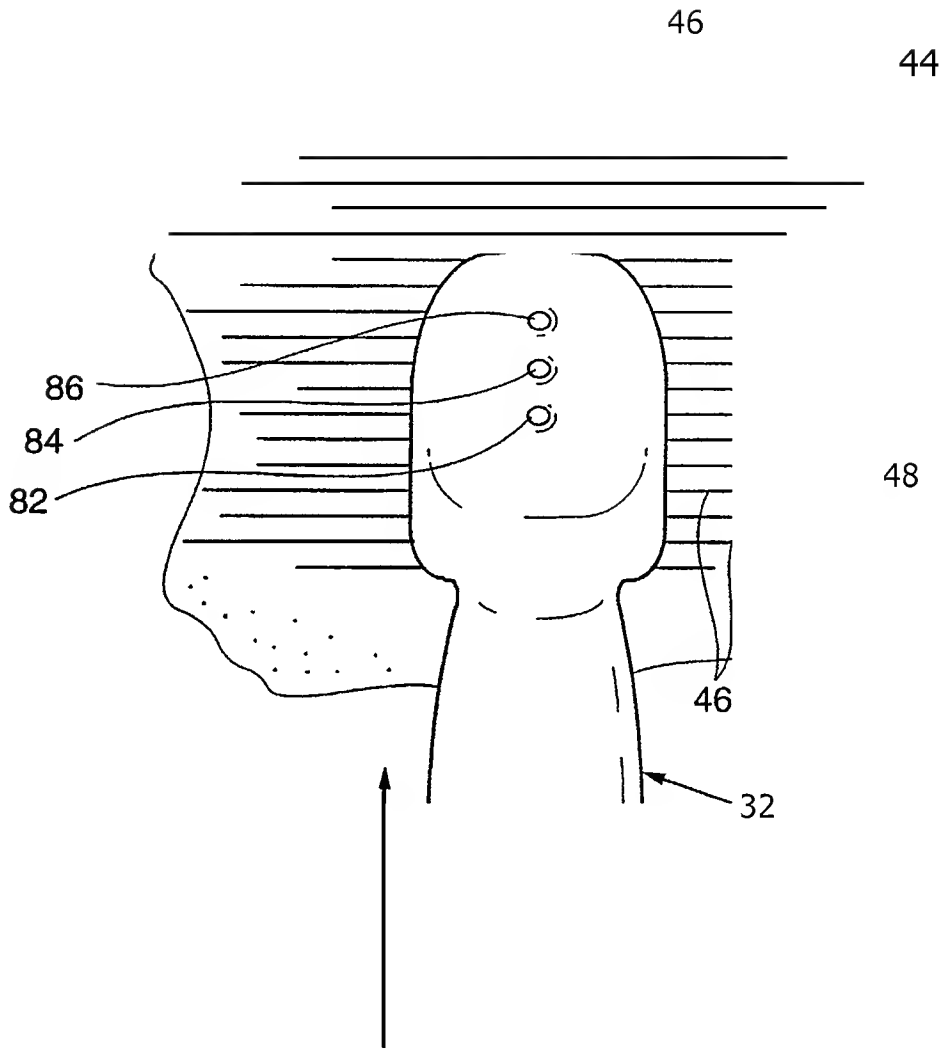


FIG. 2

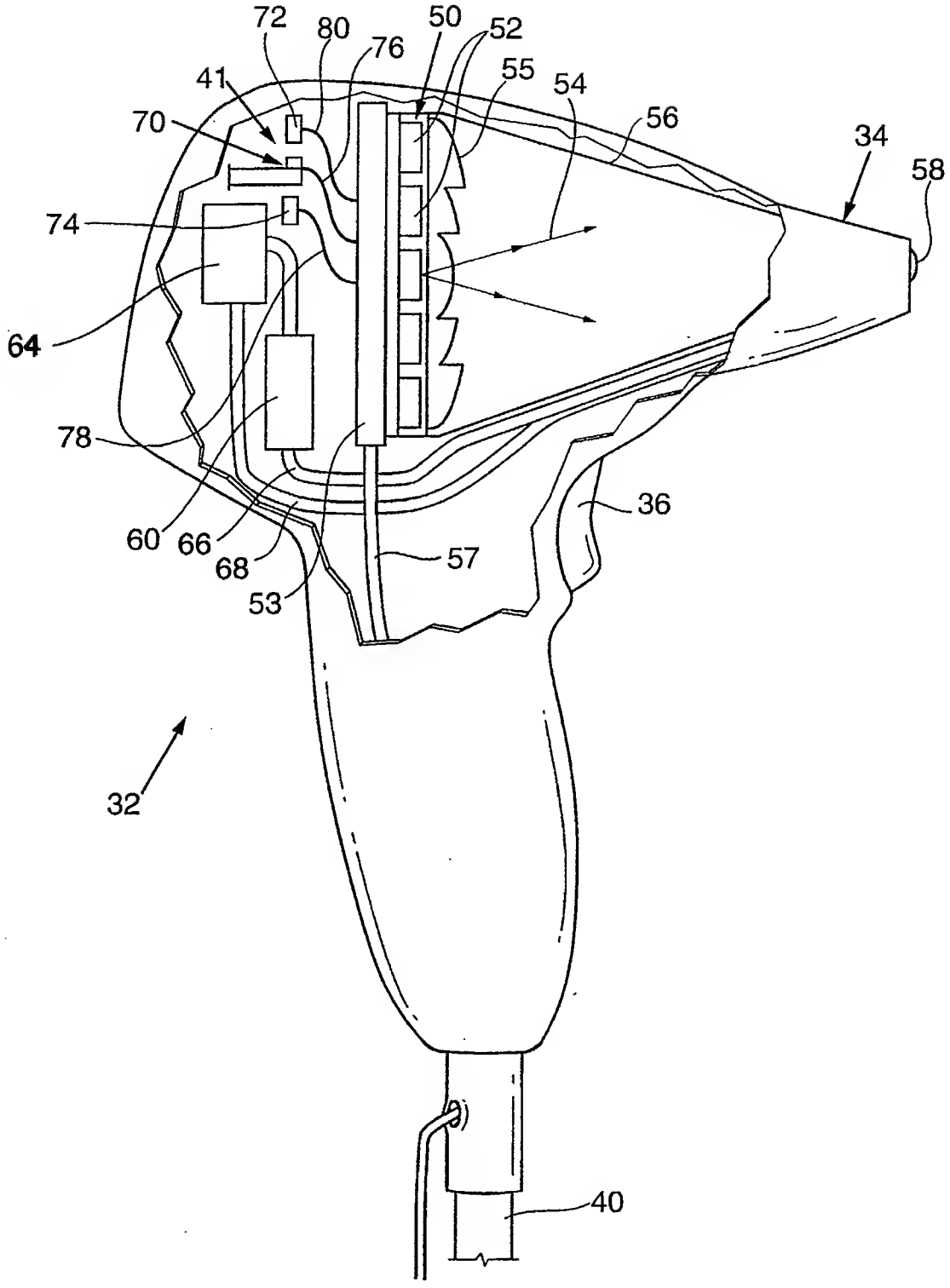


FIG.!3

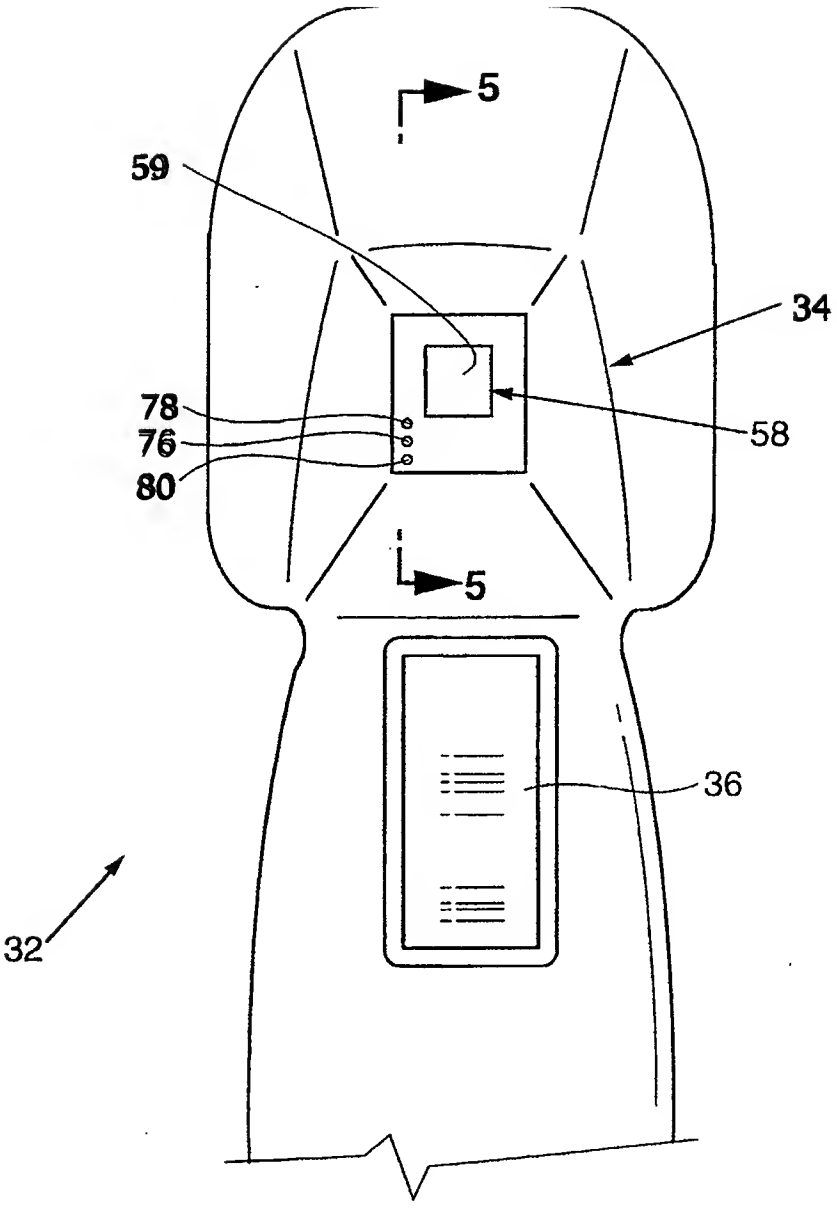
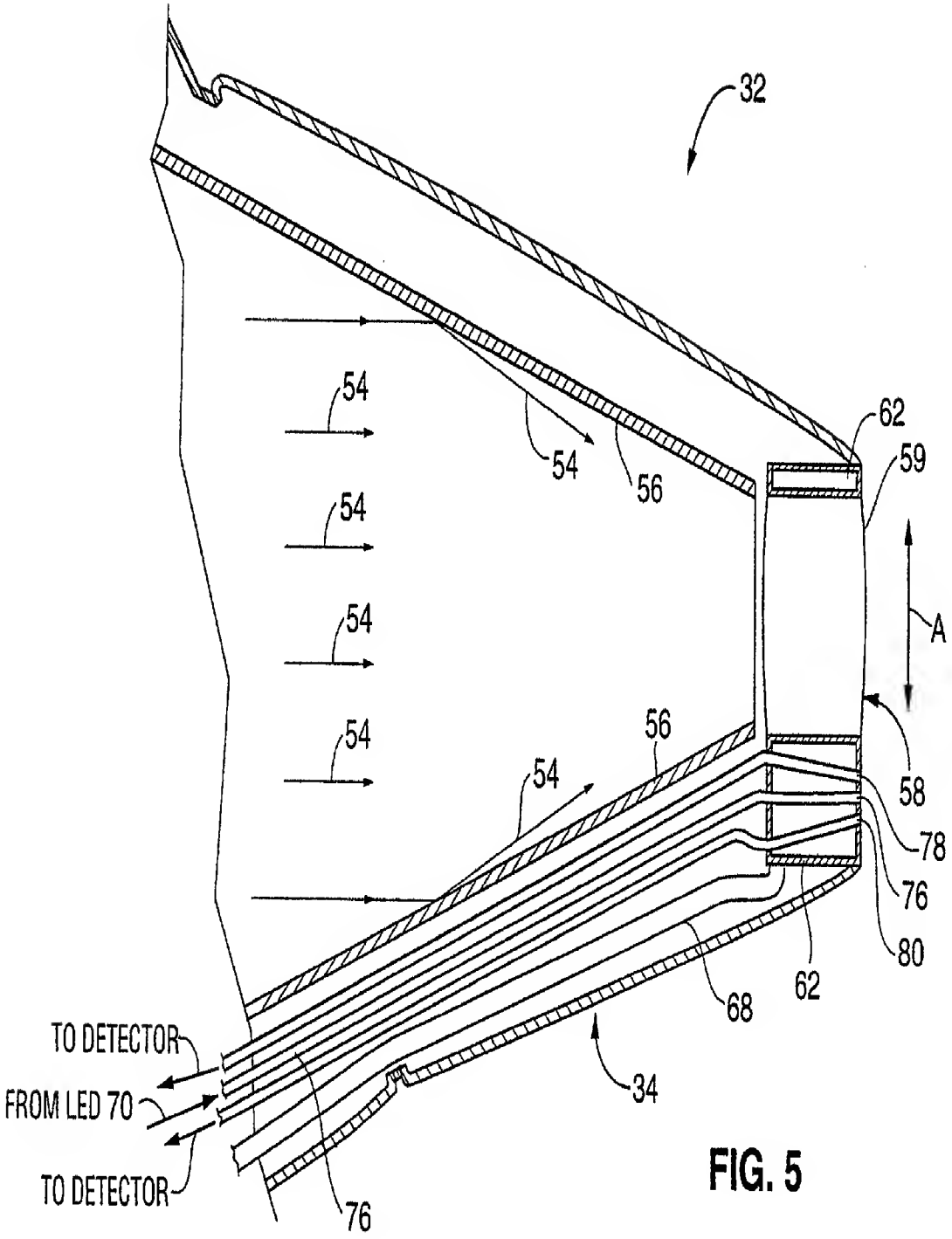


FIG. 4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FROM LED 70
TO DETECTOR
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FIG. 5

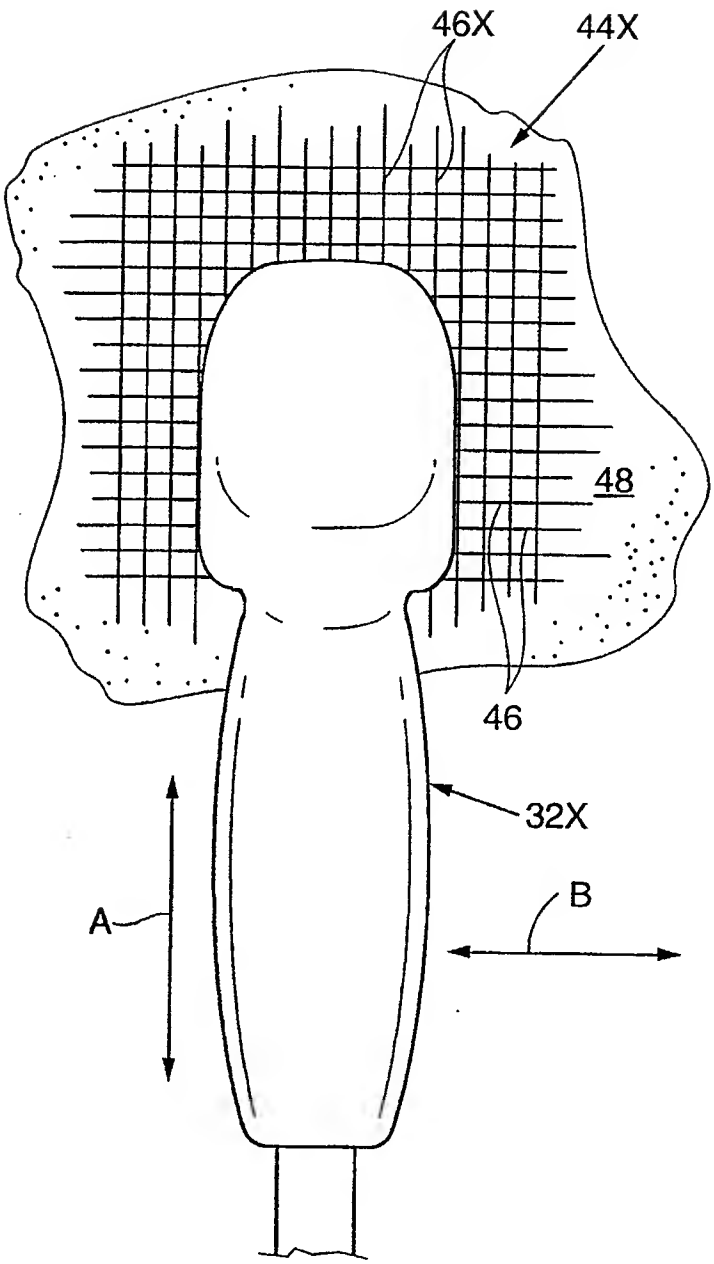


FIG. 6

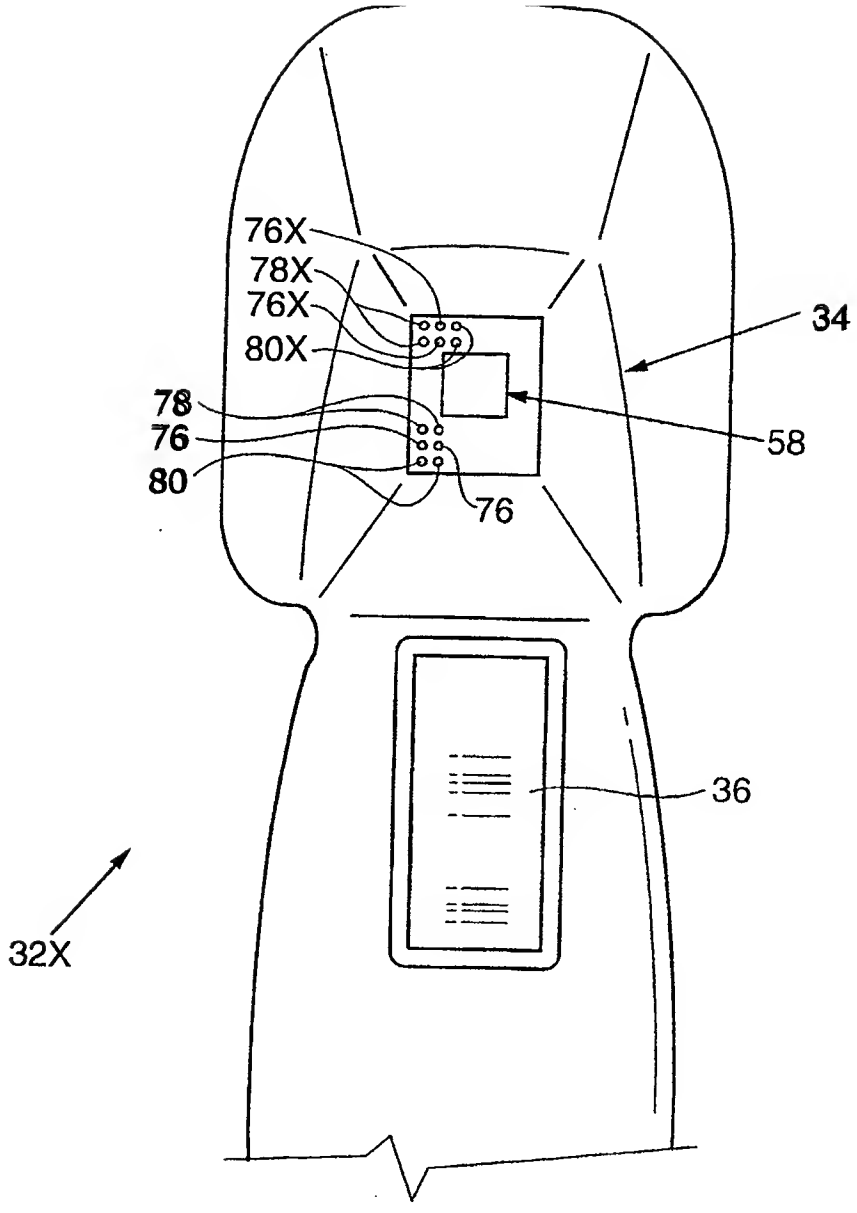


FIG. 7

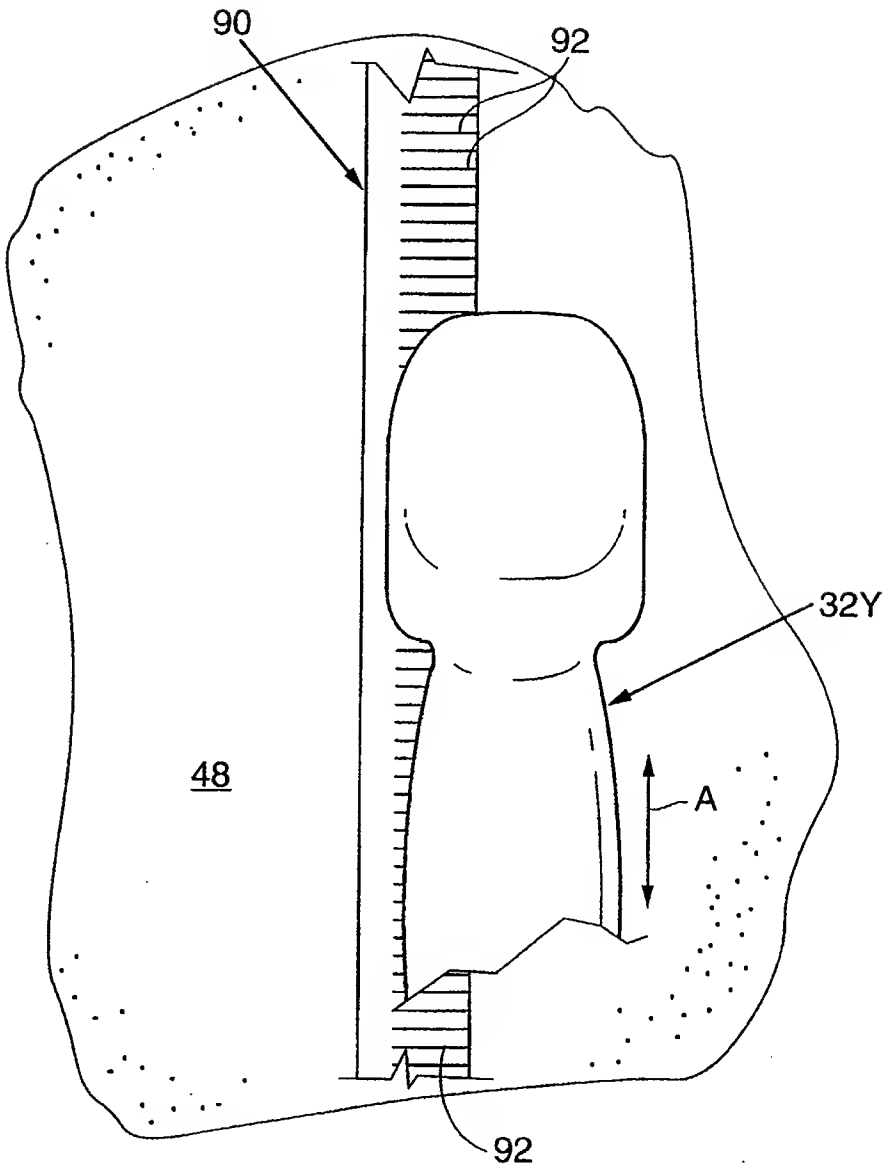
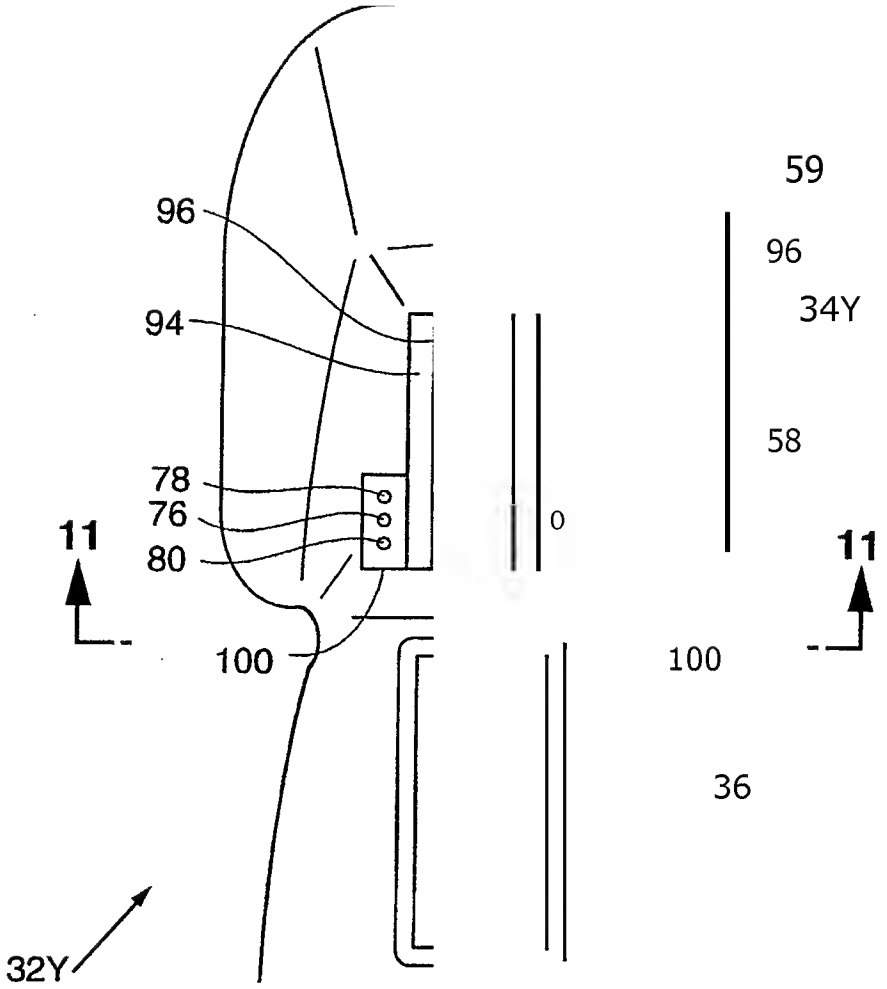


FIG. 8



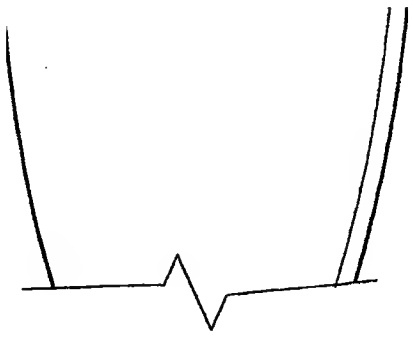


FIG. 9

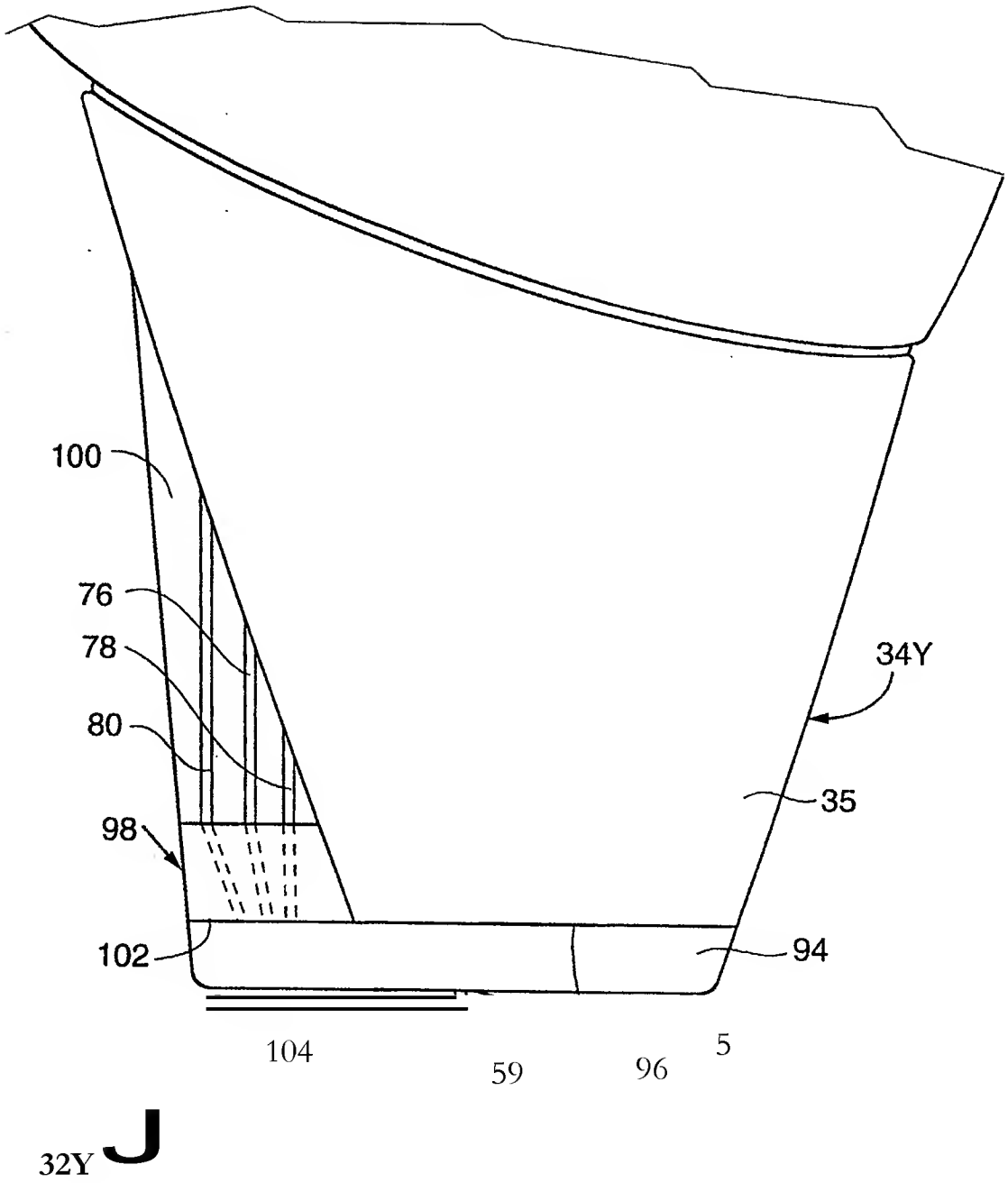


FIG. 10

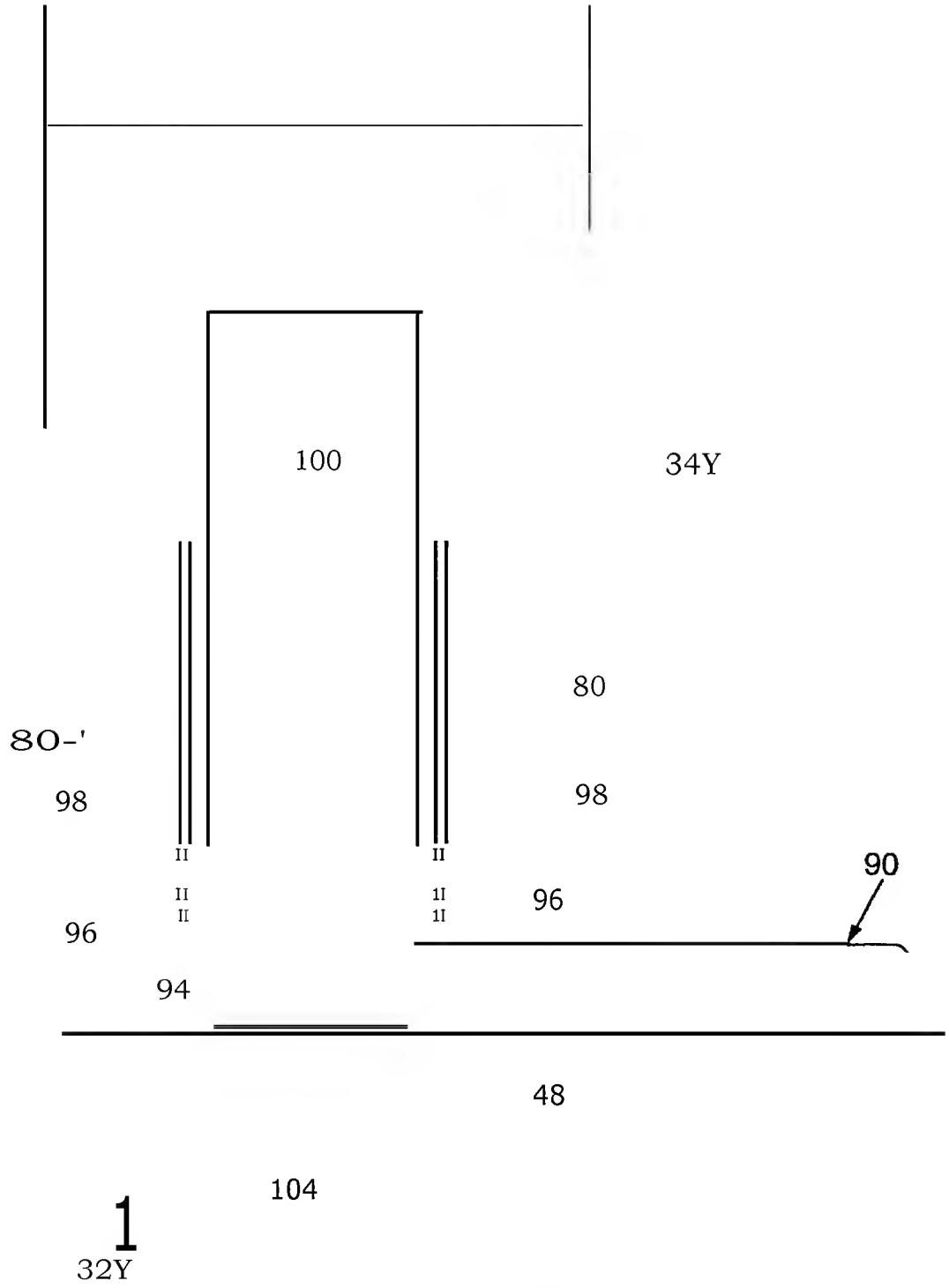


FIG. 11

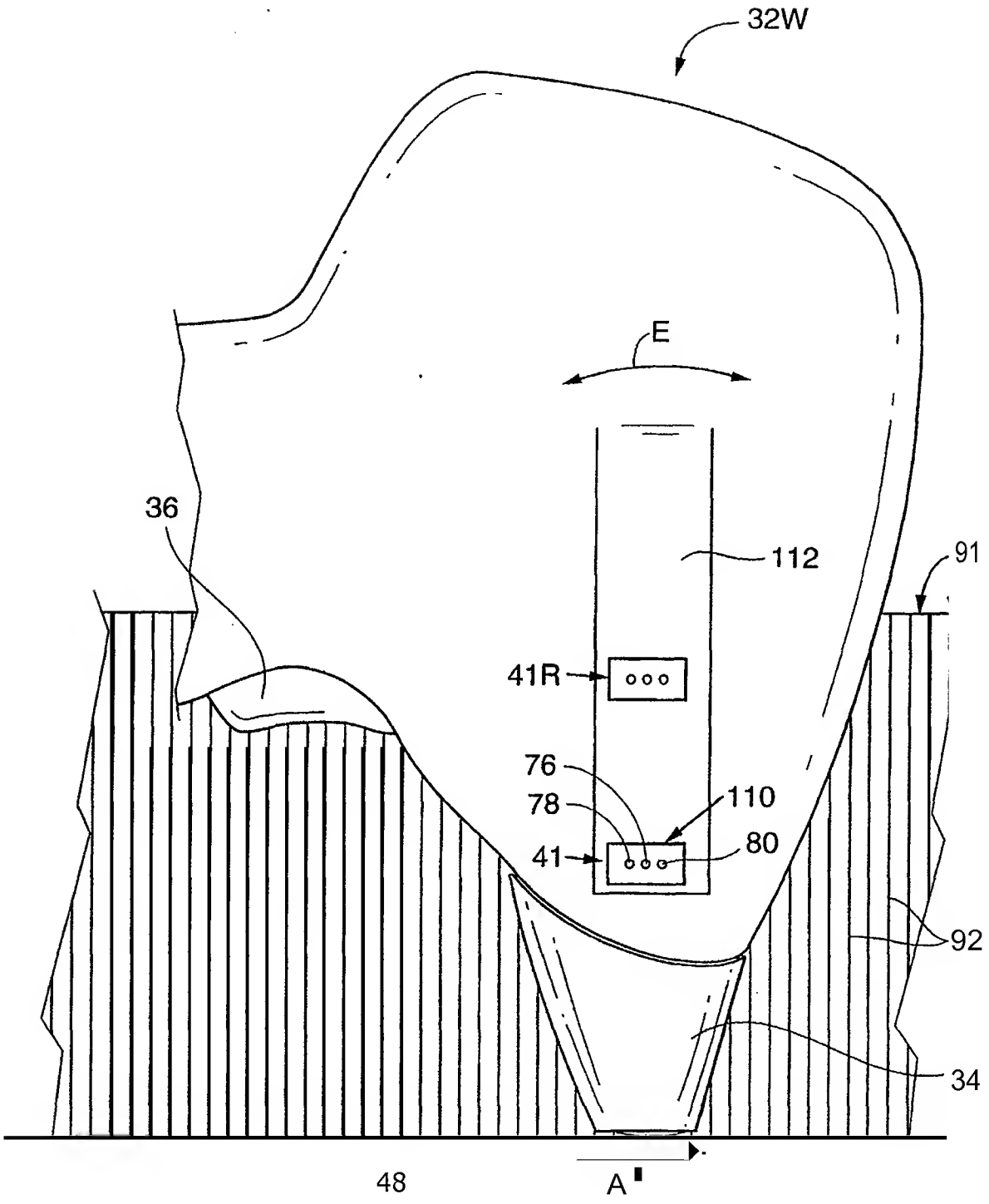


FIG. 12

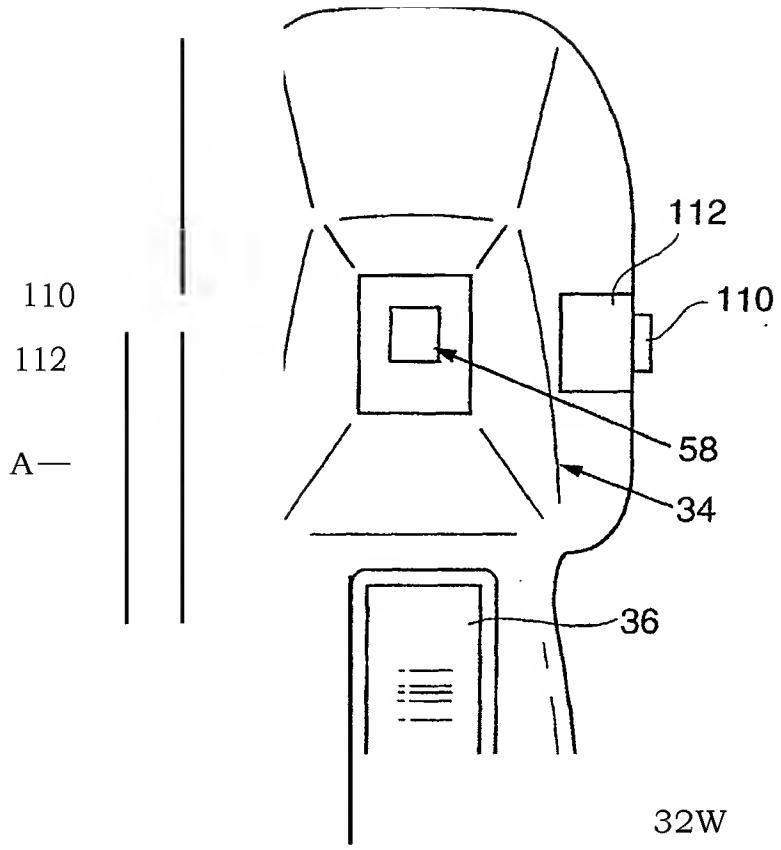


FIG.!13

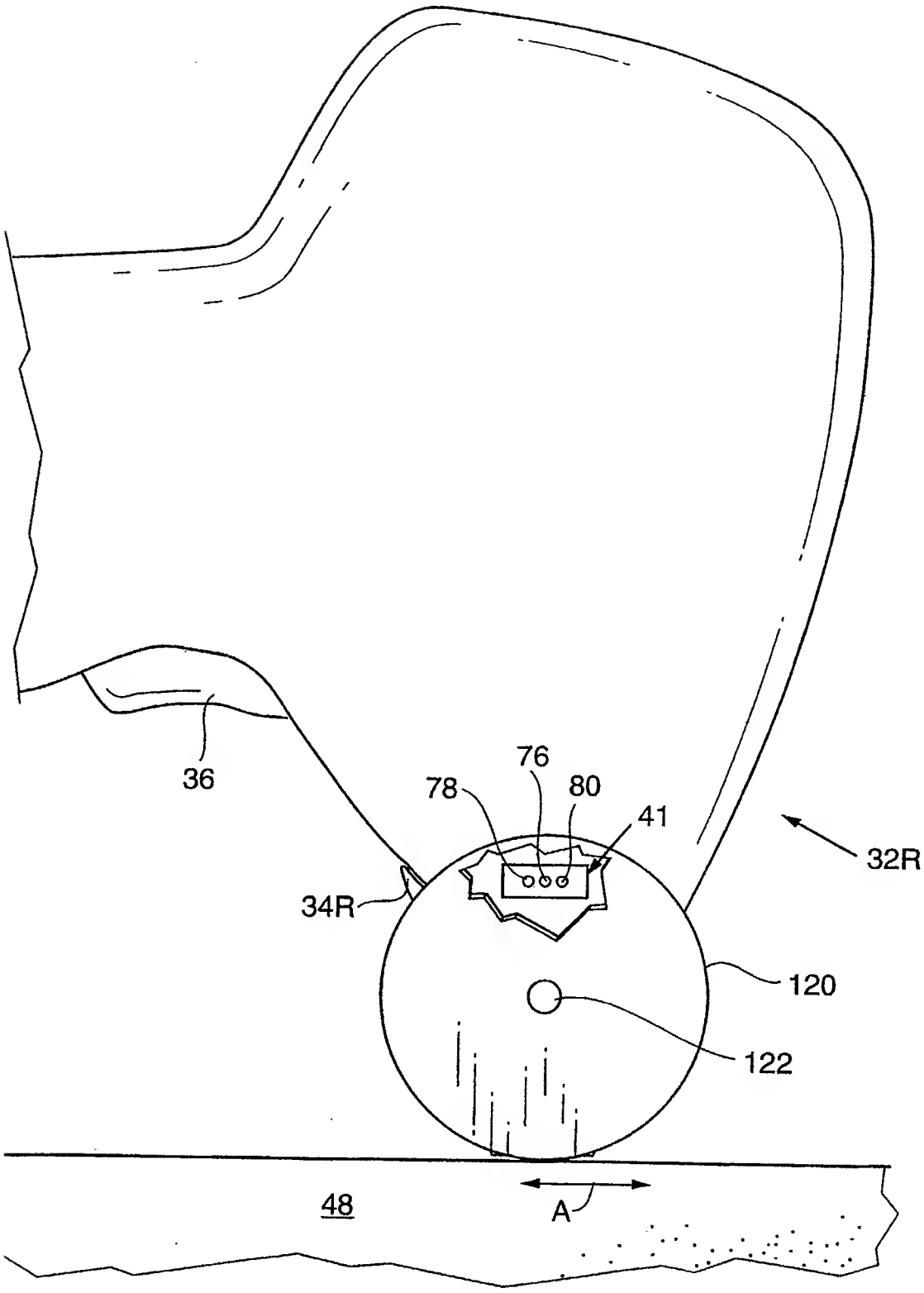


FIG. 14

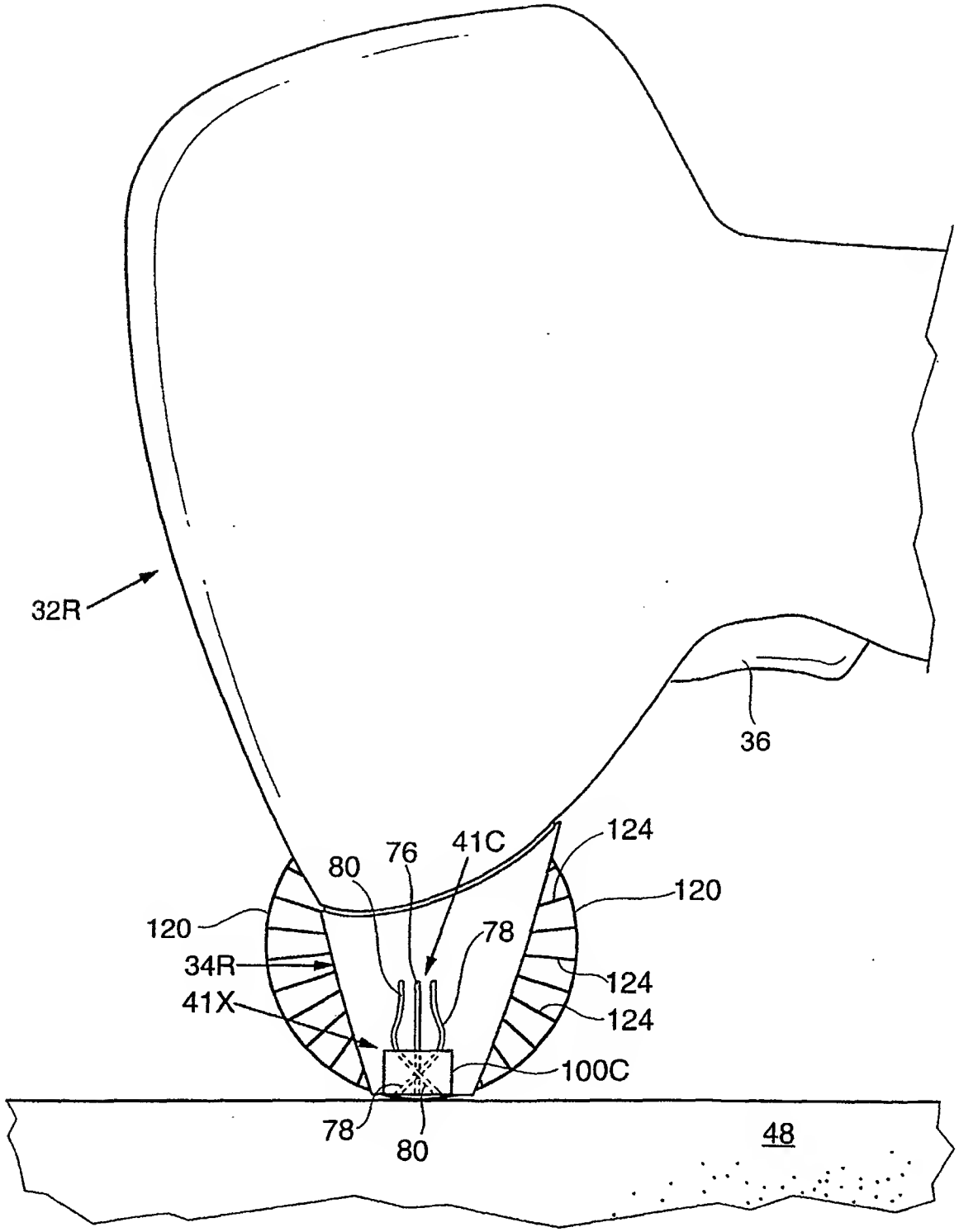


FIG. 15

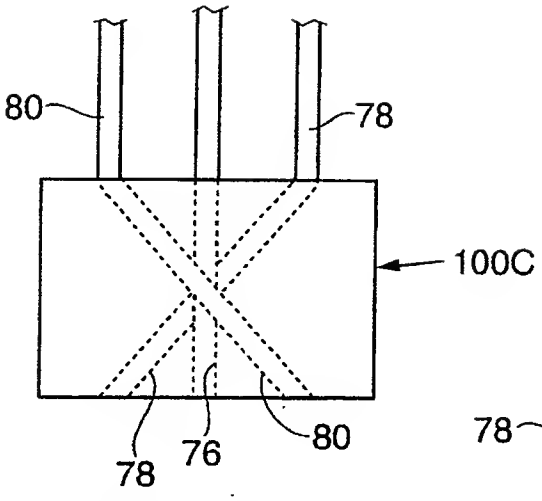


FIG. 15A

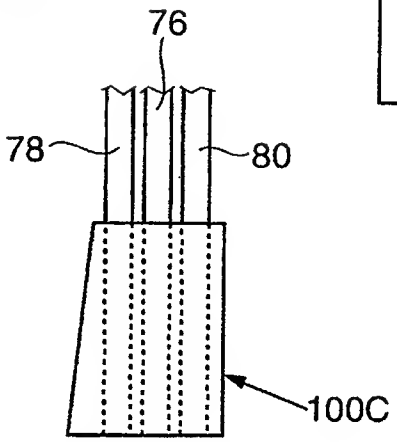


FIG. 15B

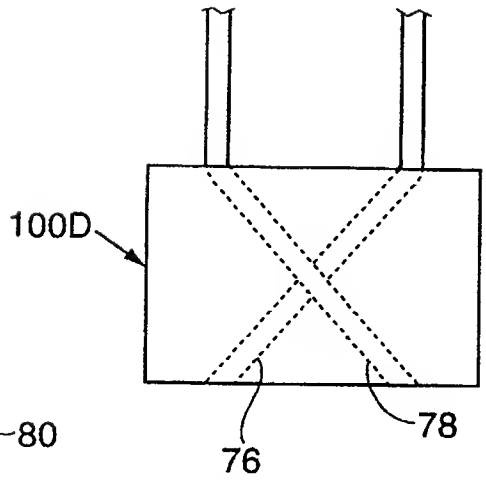


FIG. 15C

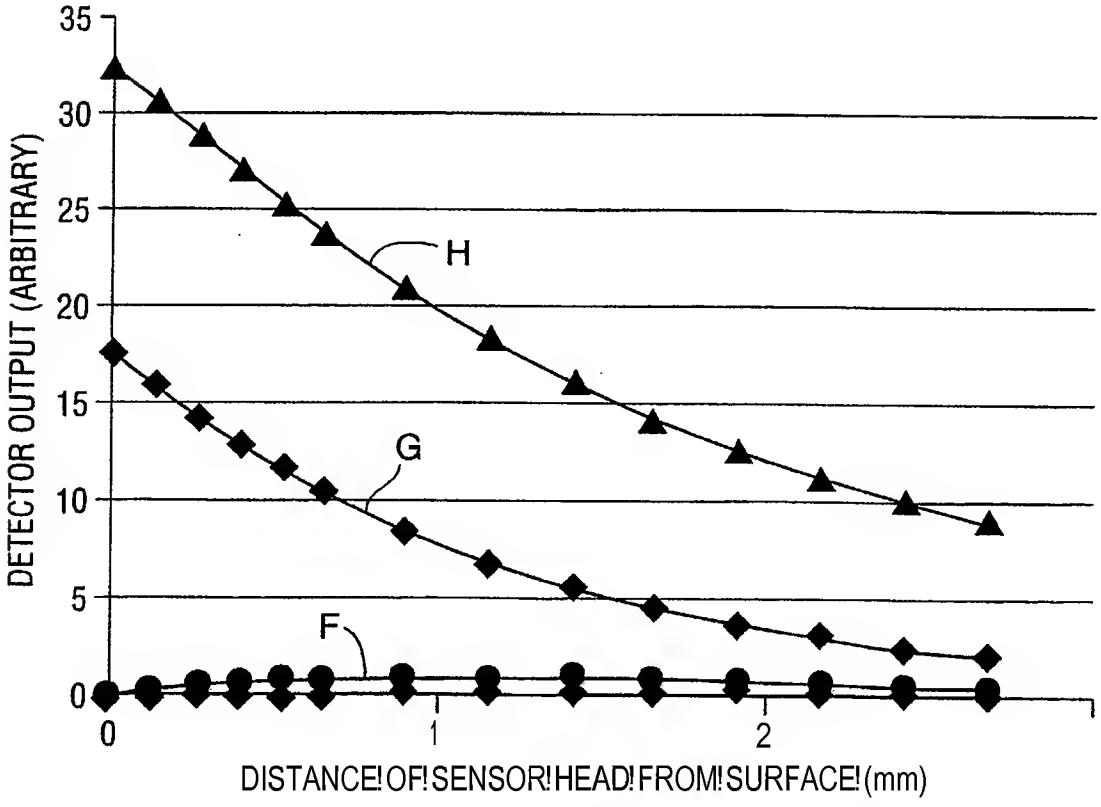


FIG. 15D

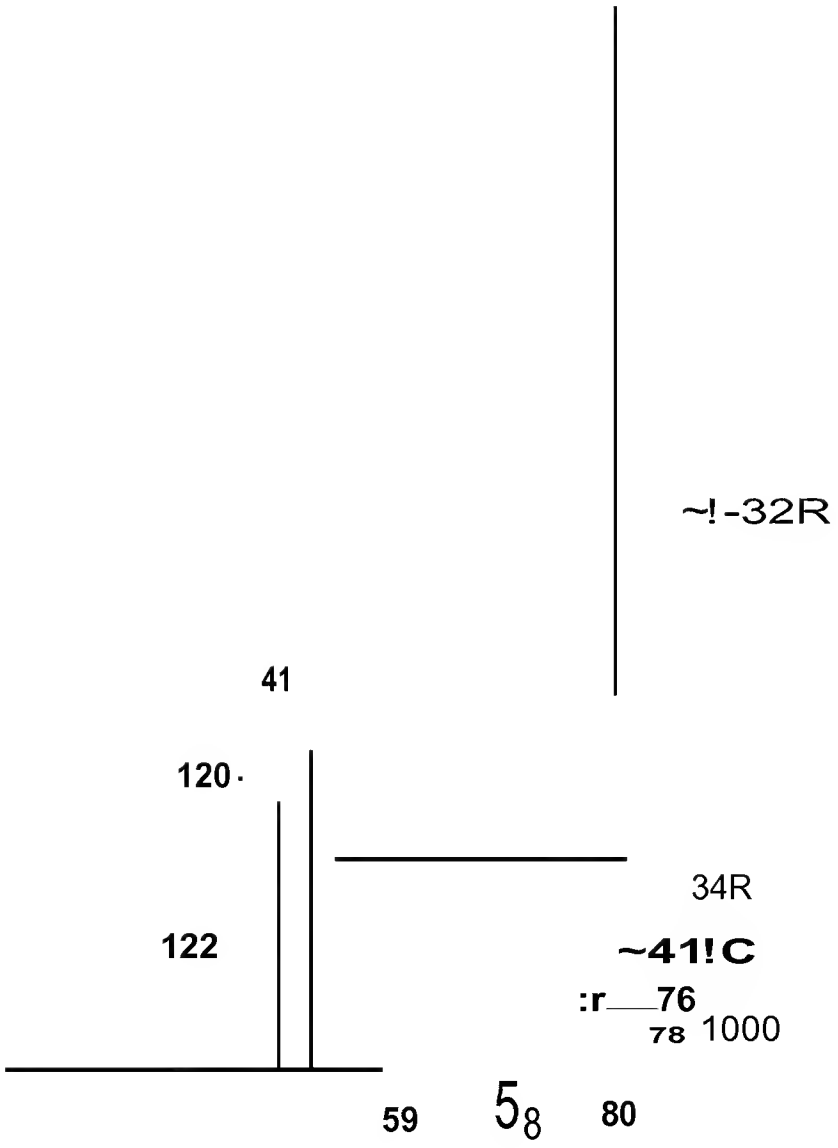


FIG. 16

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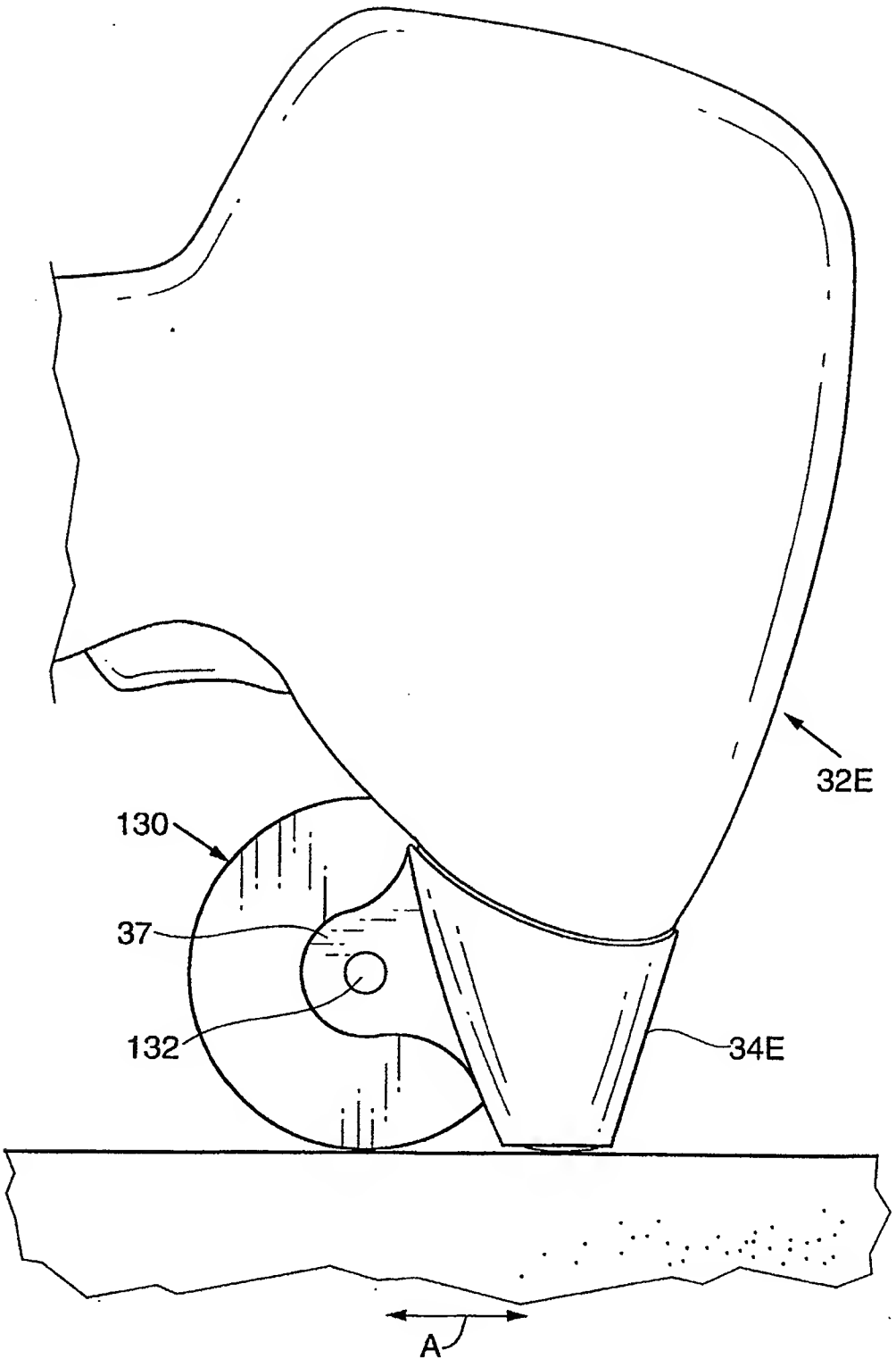

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FIG. 17

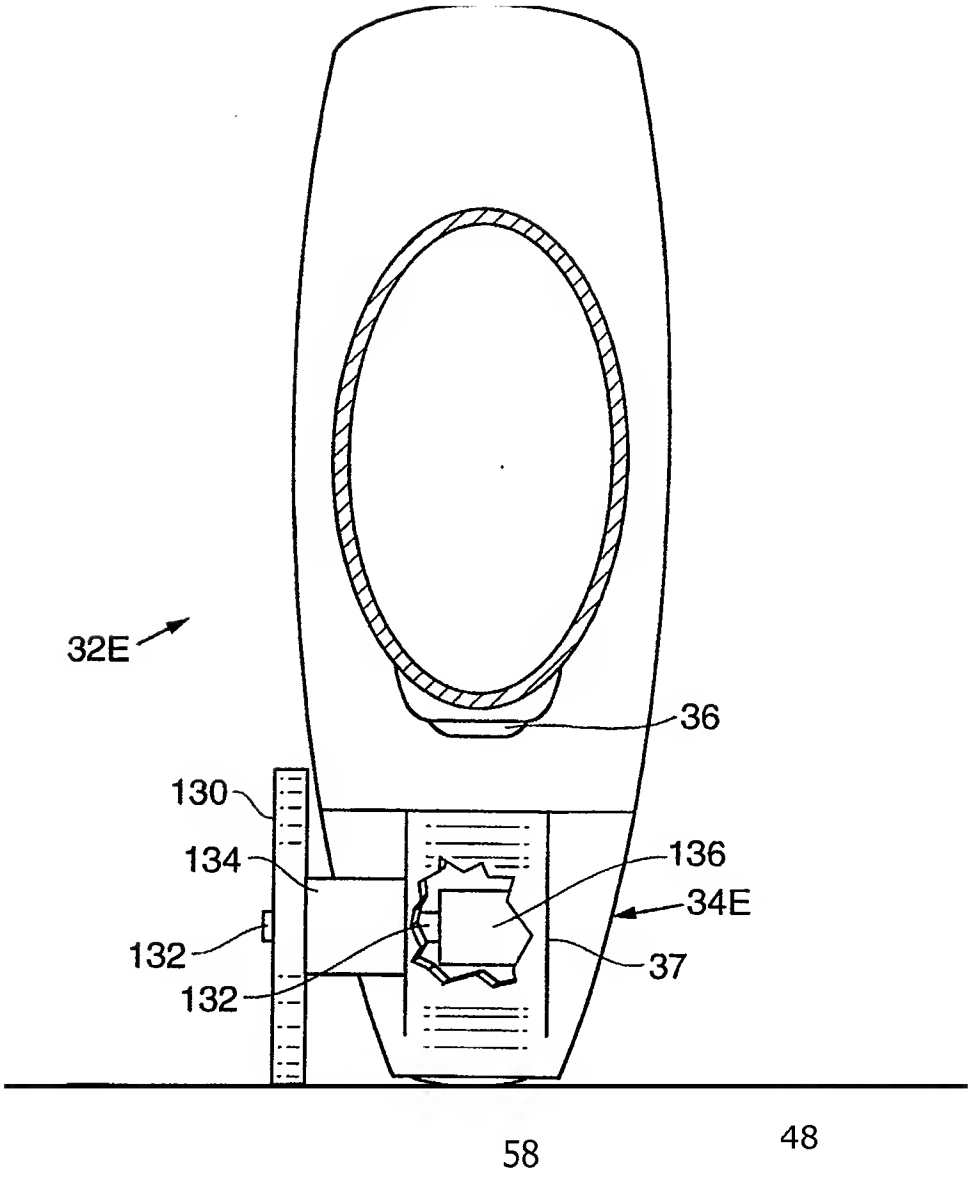

FIG. 18

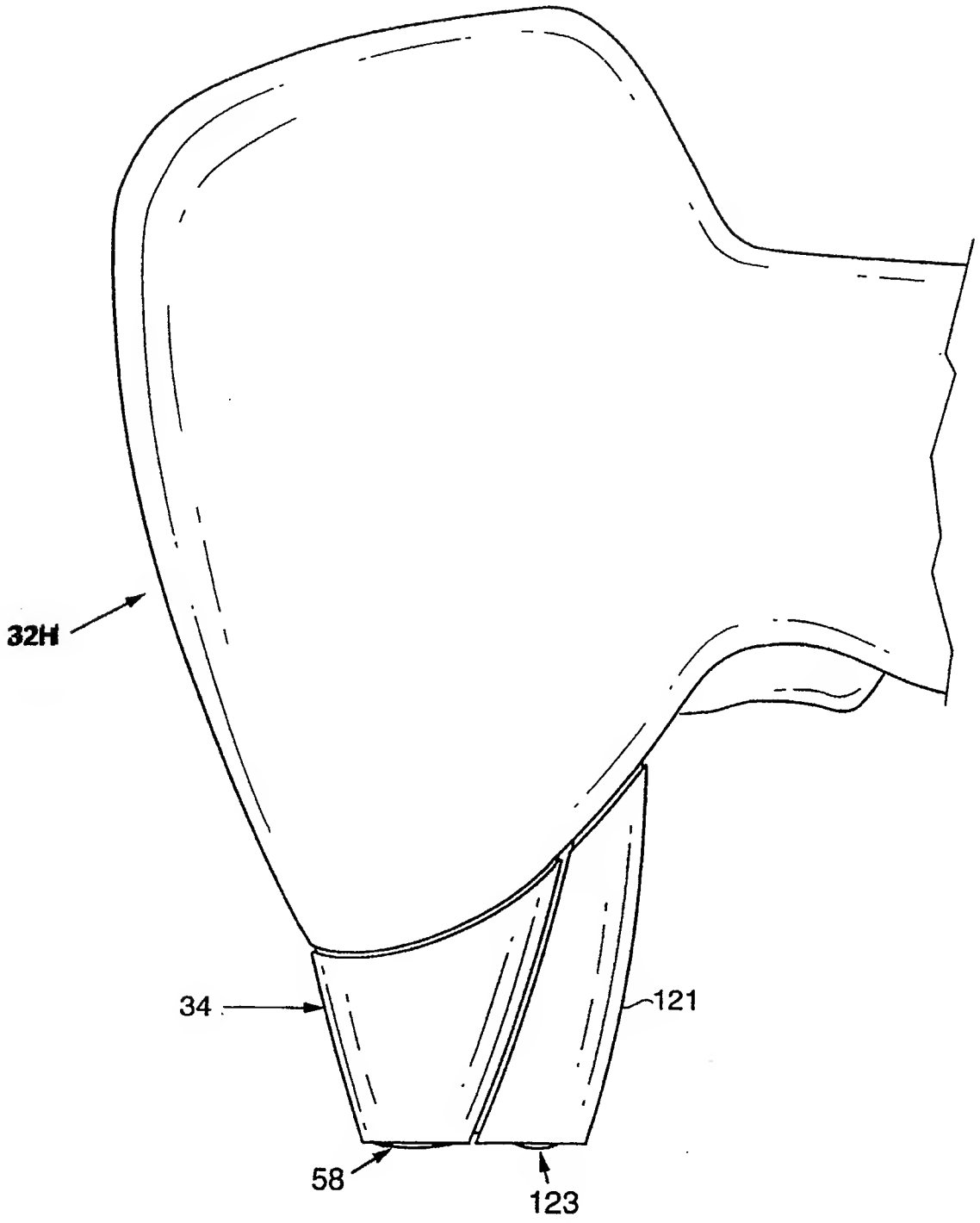

FIG.!19

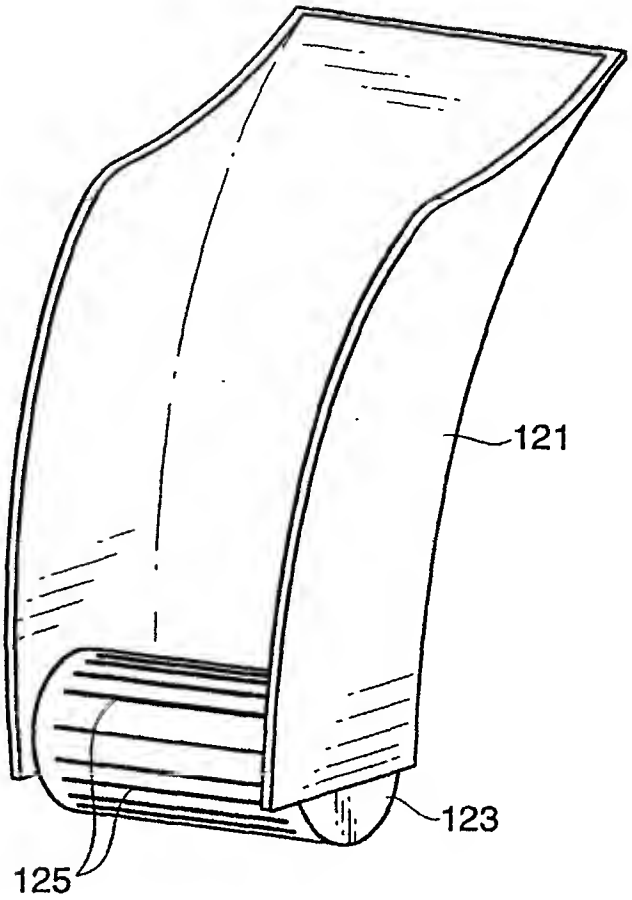

FIG. 20

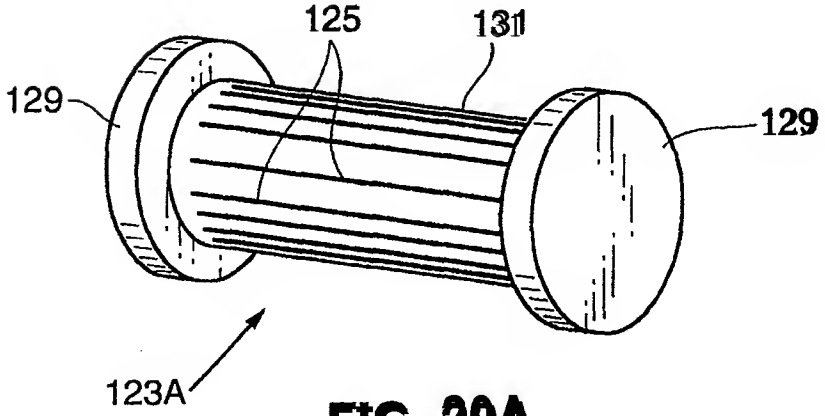

FIG. 20A

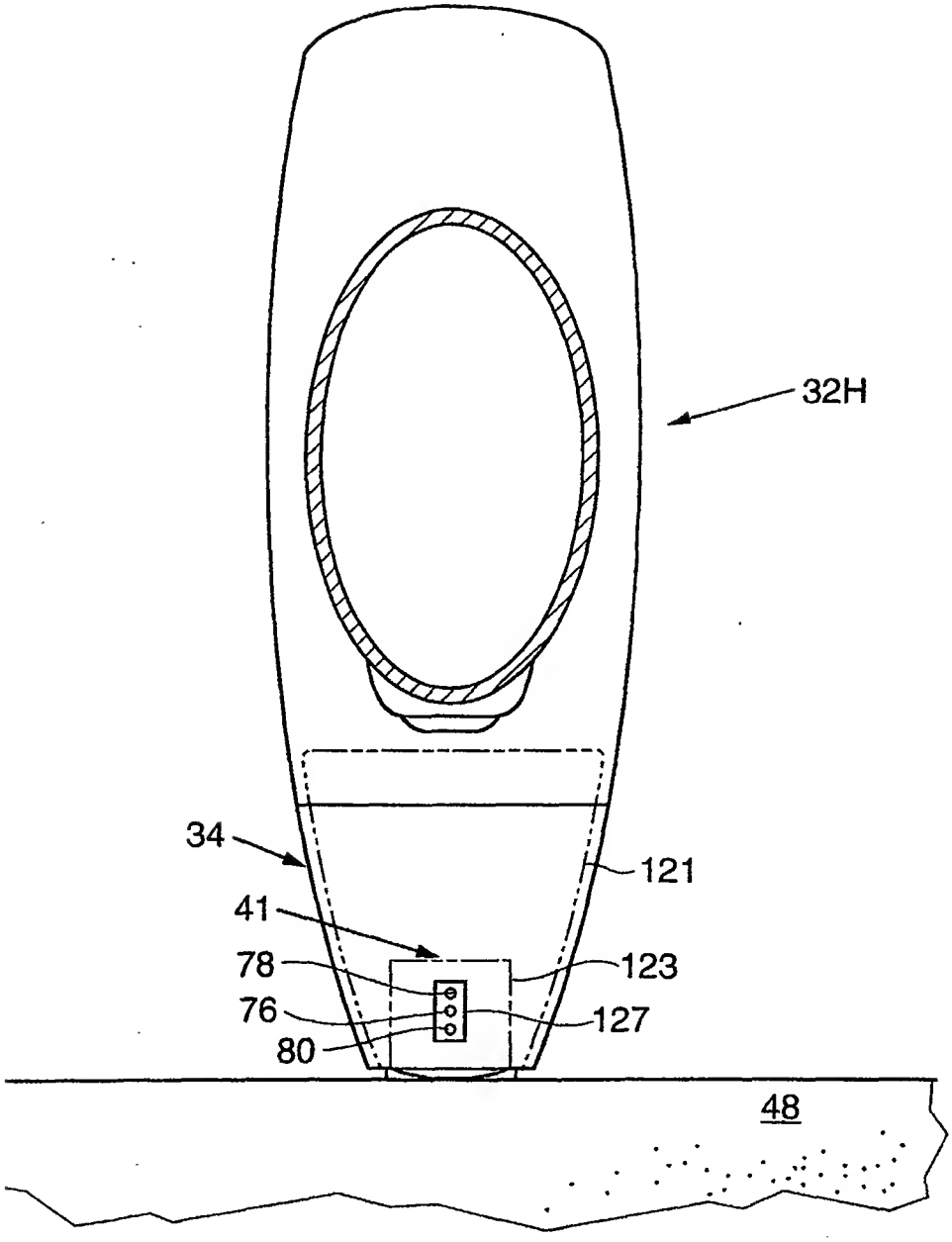

FIG. 21

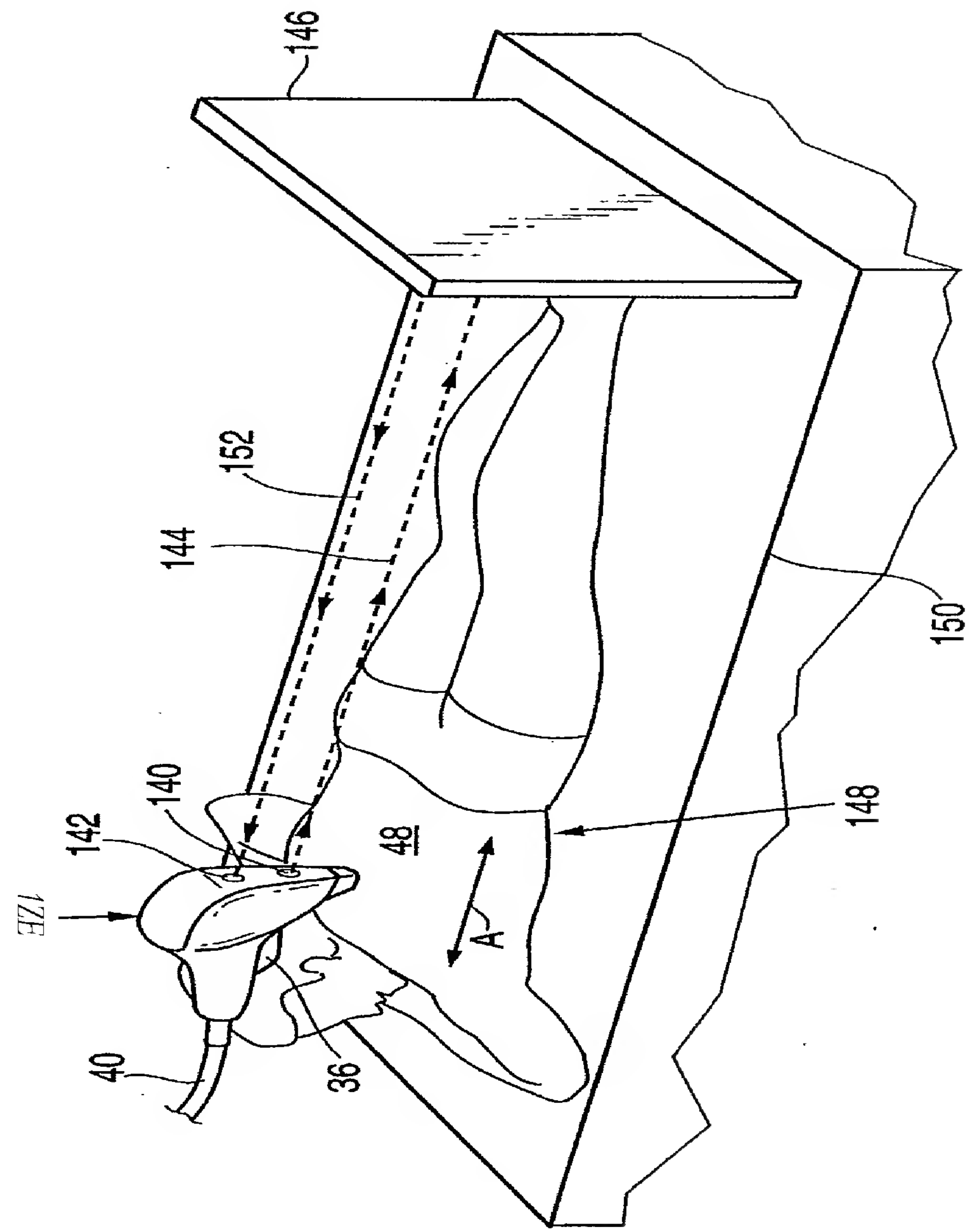

FIG. 22

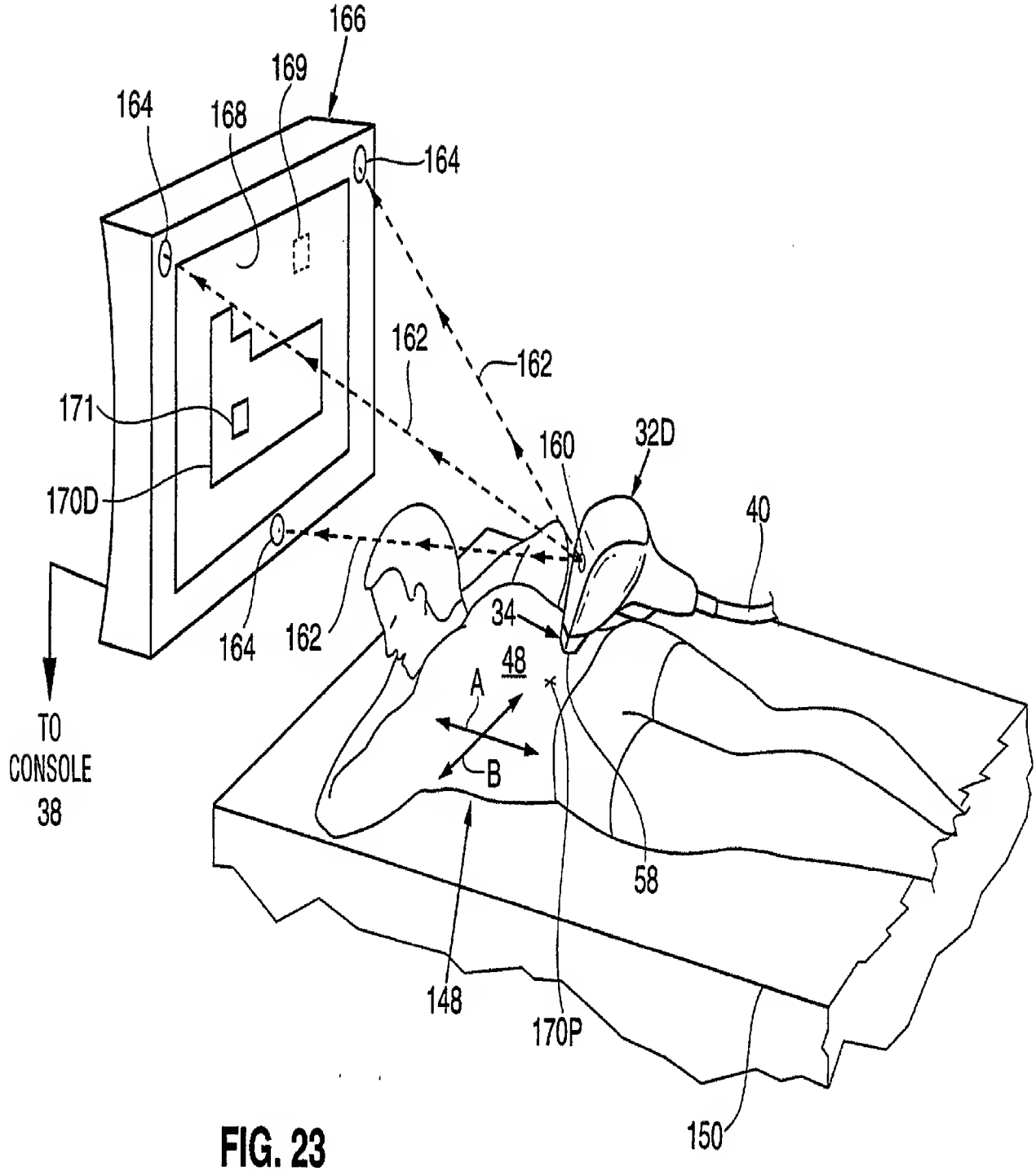
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FIG. 23

INTERNATIONAL SEARCH REPORT

Interco Application No
PCT/US 00/26534

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61 18/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 51235 A (GEN HOSPITAL CORP ;PALOMAR MEDICAL TECHNOLOGIES I (US)) 19 November 1998 (1998-11-19) page 5, line 3 - line 19 page 8, line 23 - line 31 page 18, line 7 - line 18 page 20, line 3 - line 7; figure 9	44,49,50
X	WO 99 11324 A (ALLE PETERSEN OLAV ;ASAH JARNE (DK); ASAH MEDICO A S (DK); DOLLE) 11 March 1999 (1999-03-11) column 10, line 32 -column 12, line 21	44-48
X	US 5 501 680 A (NARAYANAN KRISHNA ET AL) 26 March 1996 (1996-03-26) column 2, line 26 -column 3, line 20 column 7, line 38 - line 54 -/--	44-48

X Further documents are listed in the continuation of box C.

X Patent family members are listed in annex.

° Special categories of cited documents:

document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the international filing

L document which may throw doubts on priority claims or which is cited to establish the publication date of another citation or other special reason (as specified)

document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

later document published after the international filing date or parity date and not in conflict with the application but died to understand the principle or theory underlying the invention

document of particular relevance; the claimed Invention cannot be considered novel or cannot be considered to involve an Inventive step when the document is taken alone

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 December 2000	28/12/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel (+31-70) 340-2040, Tx 31 651 epo ni, Fax (+31-70) 340-3016	Petter, E

second sheet) (July 1992

C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 531 740 A (LACK MICHAEL) 2 July 1996 (1996-07-02) abstract	44-48
A	WO 97 22384 A (LASER IND LTD) 26 June 1997 (1997-06-26) page 4, line 6 - line 22; figures 9A,9 page 11, line 16 - page 12, line 14 page 13, line 18 - page 14, line 13 page 10, line 23 - line 26	44-48
A	EP 0 898 983 A (NIDEK KK) 3 March 1999 (1999-03-03) column 3, line 55 - column 4, line 19 column 4, line 29 - line 46 column 9, line 39 - line 54	44-50

Patent document cited!in!search report		Publication date	Patent family member(s)		Publication date
WO 9851235	A	19-11-1998	AU	7568698! A	08-12-1998
			EP	0991372 A	12-04-2000
WO 9911324	A	11-03-1999	AU	8851898! A	22-03-1999
			EP	**1009485** A	21-06-2000
			US	6074382! A	13-06-2000
US 5501680	**A**	**26-03-1996**	**NONE**		
US!5531740	**A**	**02-07-1996**	**NONE**		
WO! 9722384	**A**	**26-06-1997**	AU	704892 **B**	**06-05-1999**
			AU	1071097 A	14-07-1997
			BR	**9612145 A**	**13-07-1999**
			EP	**0874666!A**	**04-11-1998**
			US	**5868732!A**	**09-02-1999**
			US	**5879346!A**	**09-03-1999**
			GB	2308307! A	**25-06-1997**
EP 0898983	A	03-03-1999	JP	11070121 A	**16-03-1999**
			US	**5971978!A**	**26-10-1999**